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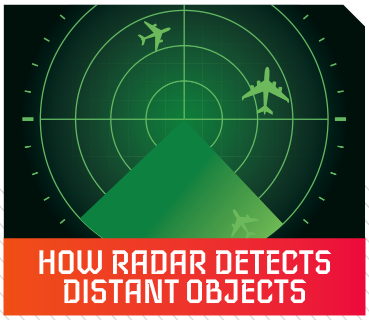

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FUTURE
ISSUE 160

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Ford Mustang GT
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The sixth generation Ford Mustang (S550) is the current iteration of the Mustang pony car manufactured by Ford. In departure from prior Mustang models, the sixth generation Mustang includes fully independent rear suspension on all models, as well as an optional 2.3L EcoBoost turbocharged and direct injected four-cylinder engine. The new Mustang was introduced as a 2015 model year vehicle, marking the fiftieth anniversary of the Ford Mustang, which was revealed as a 1965 model year vehicle on April 17, 1964. The sixth generation is also the first Ford Mustang to be marketed and sold globally, and represented the first time that factory right hand drive Mustangs were produced in addition to the left hand drive models.

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“The spill directly affected 70,000 square miles of ocean”

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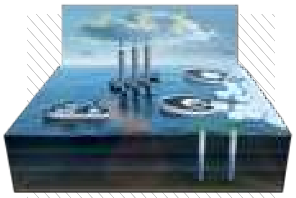

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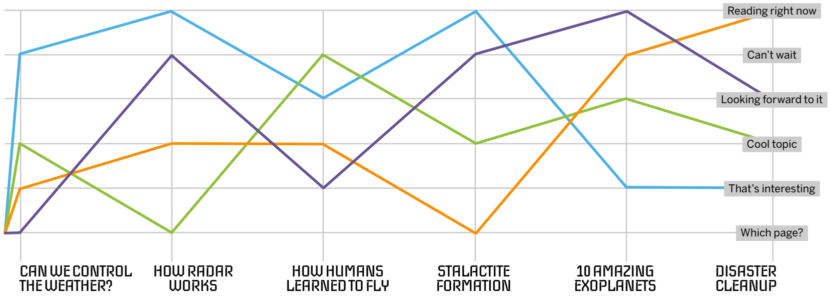
HOW IT WORKS
DISASTER CLEANUP

The evolution of our big brains is the single most distinctive feature of *Homo sapiens*. Human ingenuity has taken us from our hunter-gatherer origins, merely surviving alongside other species, to sending astronauts up to an orbiting space station while millions of us watch a live rocket launch from thousands of miles away. We have become masters of our own destiny on Earth, yet it’s been proven time and time again that we’re more than capable of ruining our planet for ourselves and for other living things. In this issue, we look at how we caused some of the worst disasters in recent history and how we went about cleaning up the terrible messes that we made. Enjoy!

Ben Biggs
EDITOR

WHAT WE’RE ANTICIPATING



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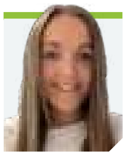

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MEET THIS ISSUE'S EXPERTS

JAMES HORTON

James has a PhD in evolutionary biology and works primarily in microbiology. He's an experienced science journalist, having written for a number of science magazines.

DR ANDREW MAY

Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

MIKE JENNINGS

Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

LAURA MEARS

Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

MARK SMITH

A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

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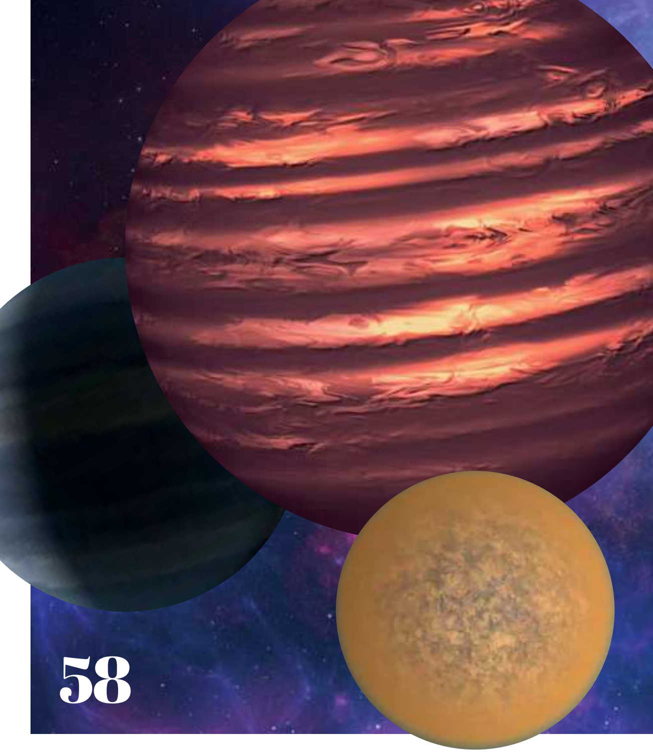

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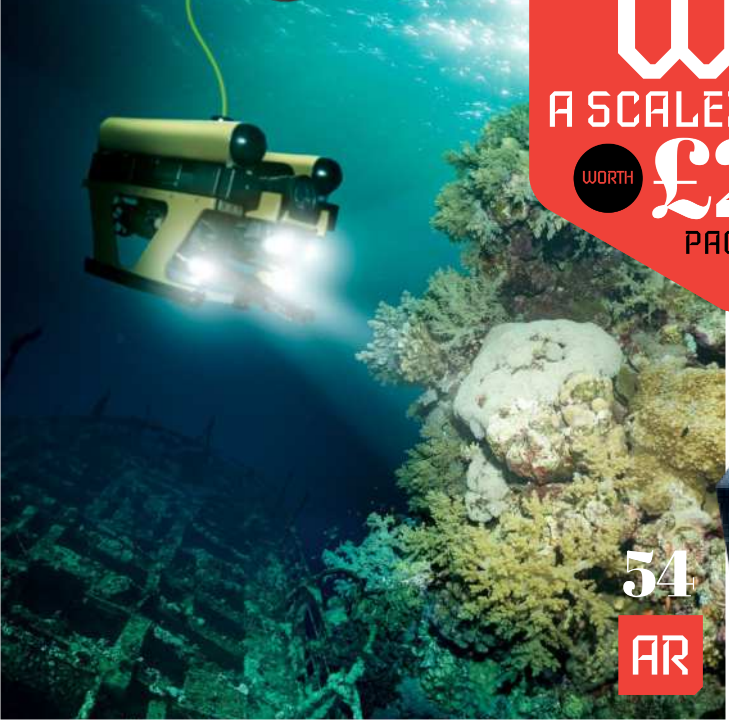

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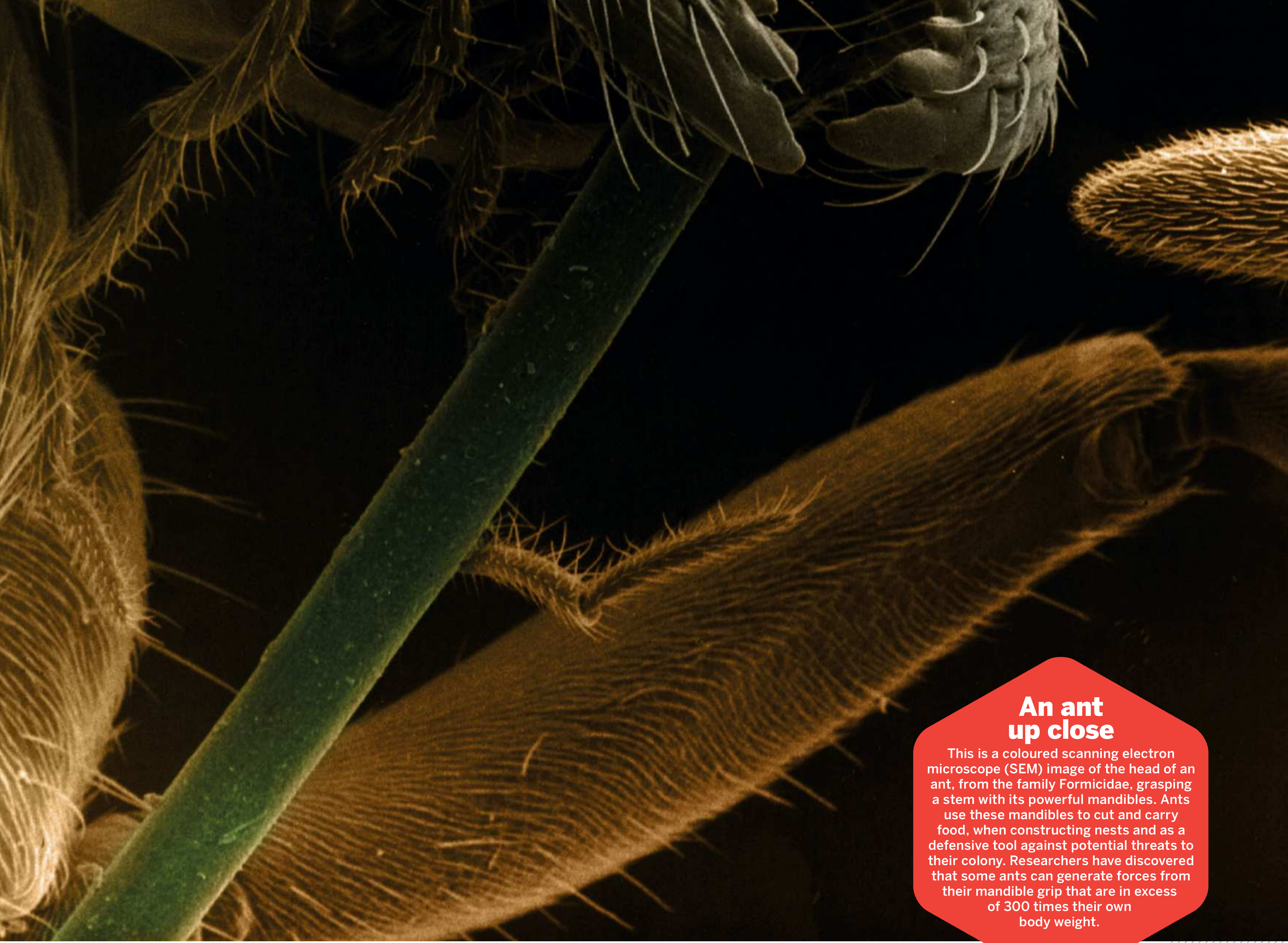

An ant up close

This is a coloured scanning electron microscope (SEM) image of the head of an ant, from the family Formicidae, grasping a stem with its powerful mandibles. Ants use these mandibles to cut and carry food, when constructing nests and as a defensive tool against potential threats to their colony. Researchers have discovered that some ants can generate forces from their mandible grip that are in excess of 300 times their own body weight.

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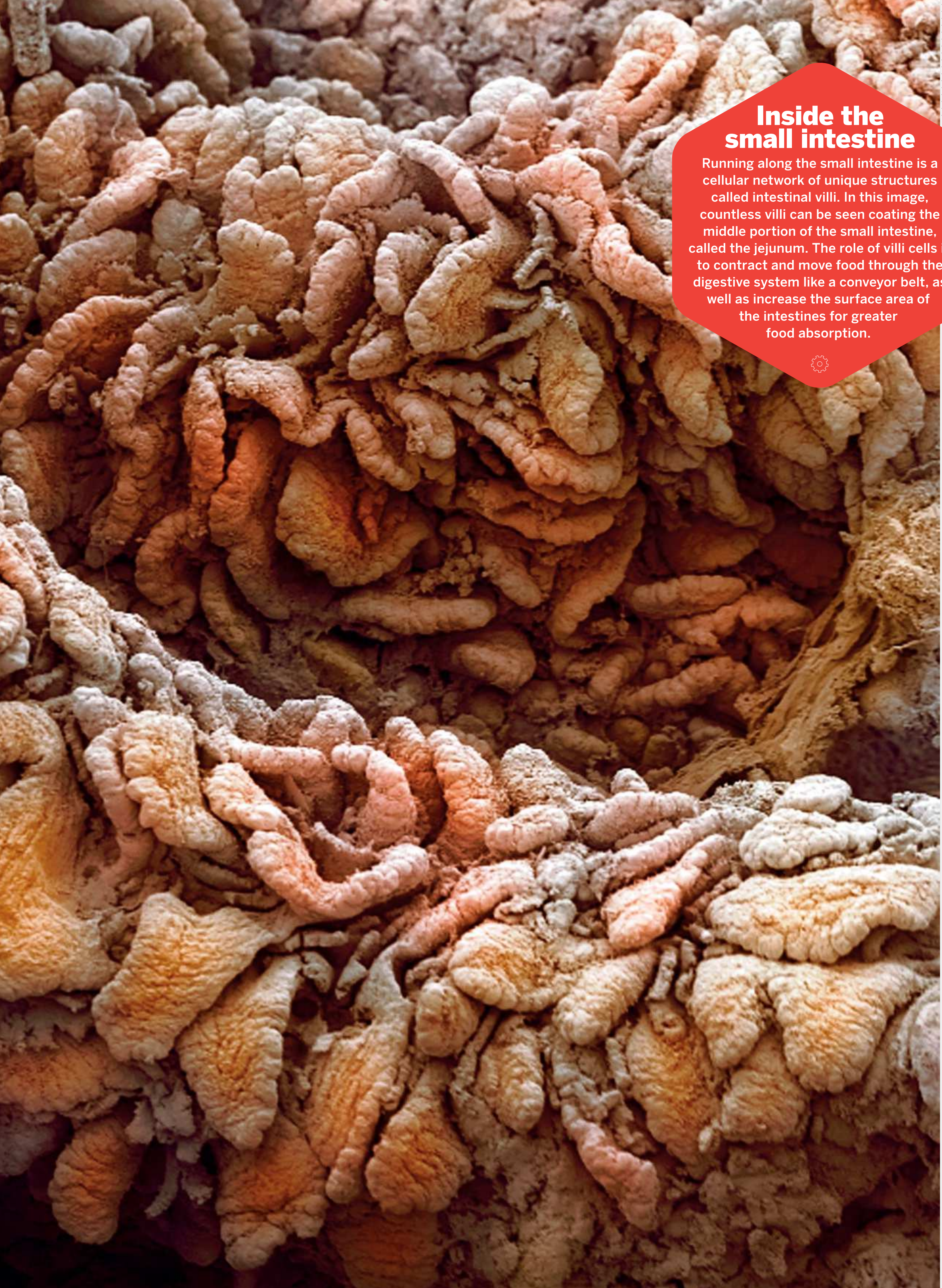

Inside the small intestine

Running along the small intestine is a cellular network of unique structures called intestinal villi. In this image, countless villi can be seen coating the middle portion of the small intestine, called the jejunum. The role of villi cells is to contract and move food through the digestive system like a conveyor belt, as well as increase the surface area of the intestines for greater food absorption.

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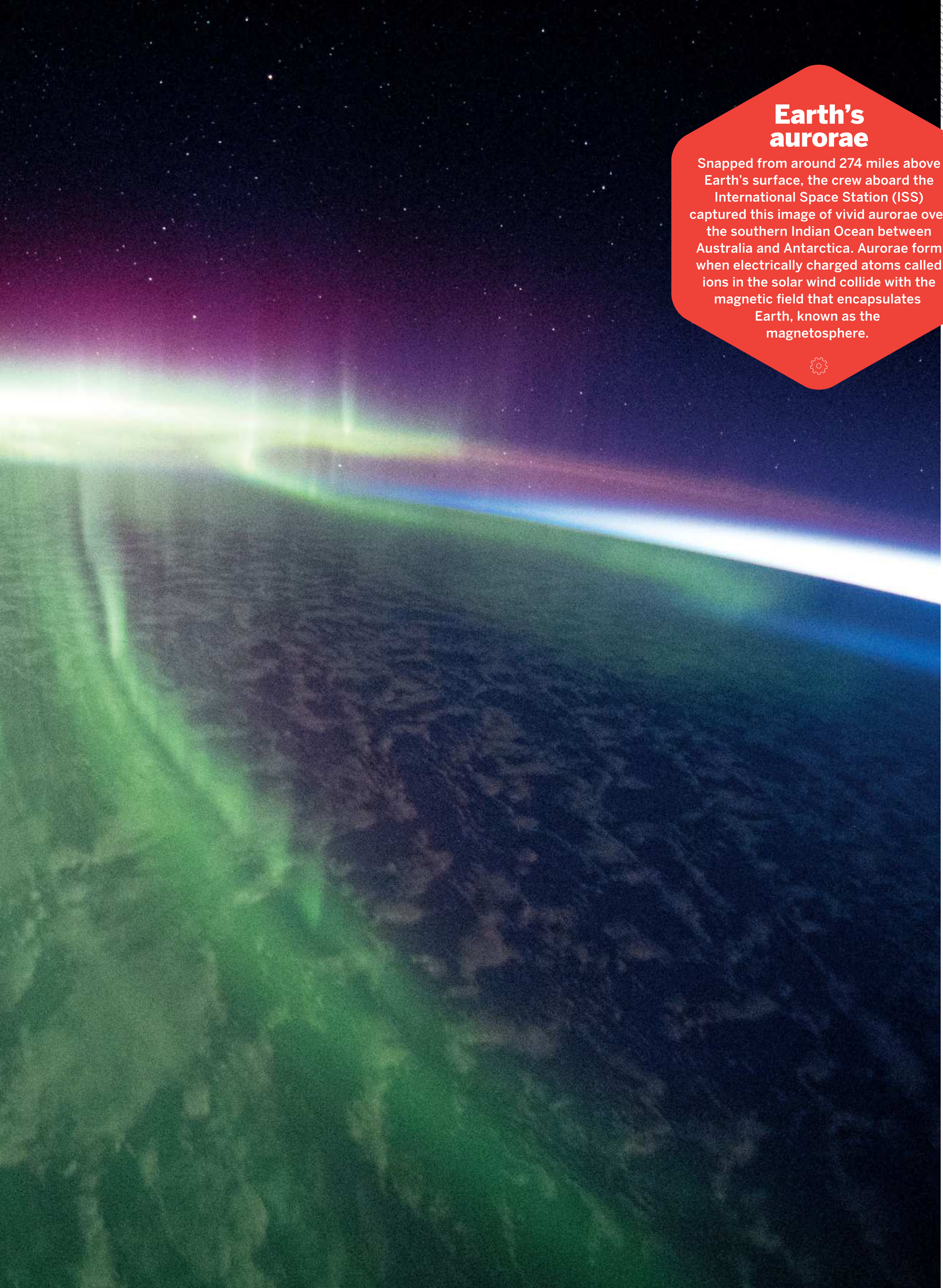

Earth's aurorae

Snapped from around 274 miles above Earth's surface, the crew aboard the International Space Station (ISS) captured this image of vivid aurorae over the southern Indian Ocean between Australia and Antarctica. Aurorae form when electrically charged atoms called ions in the solar wind collide with the magnetic field that encapsulates Earth, known as the magnetosphere.

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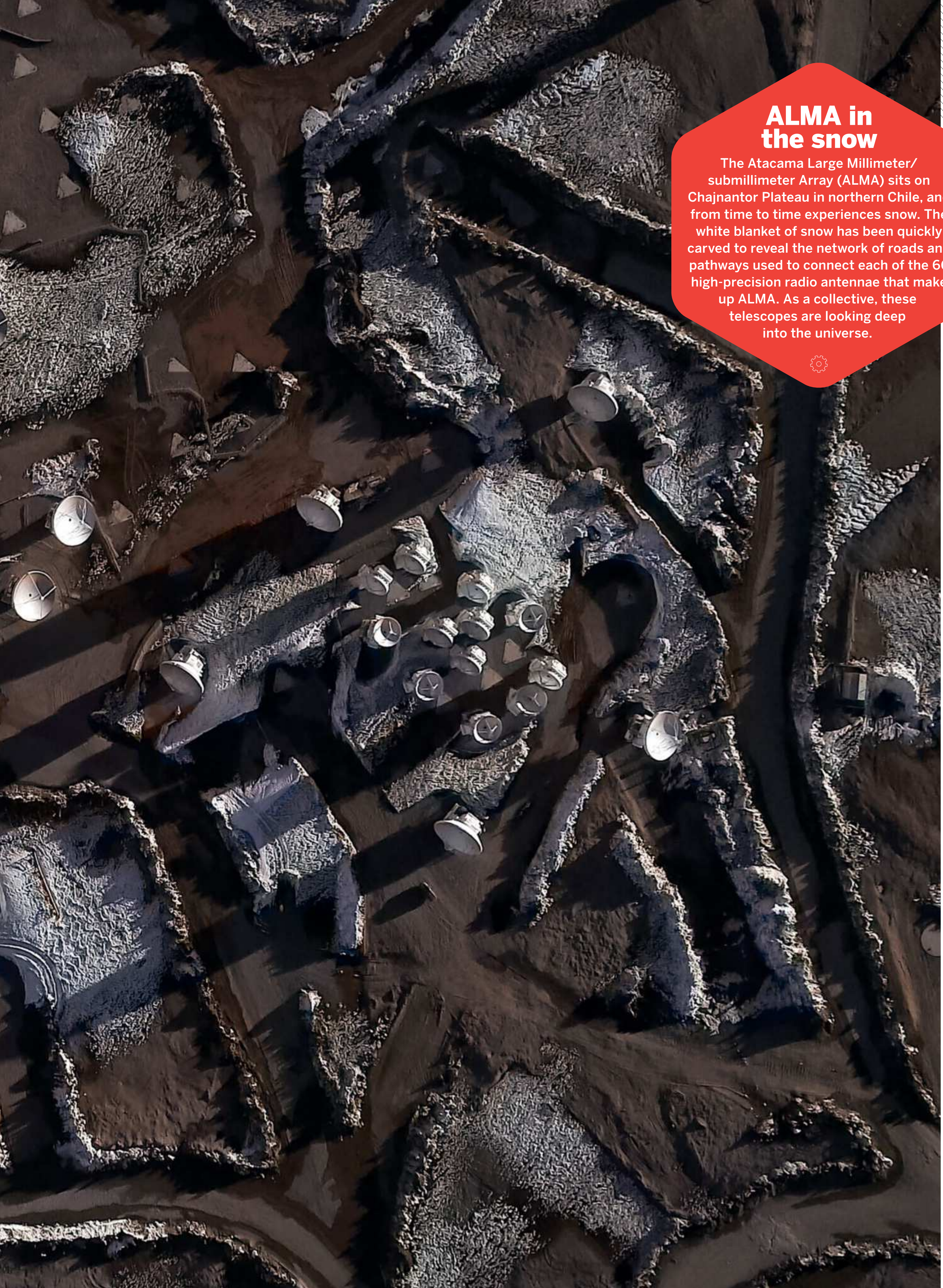
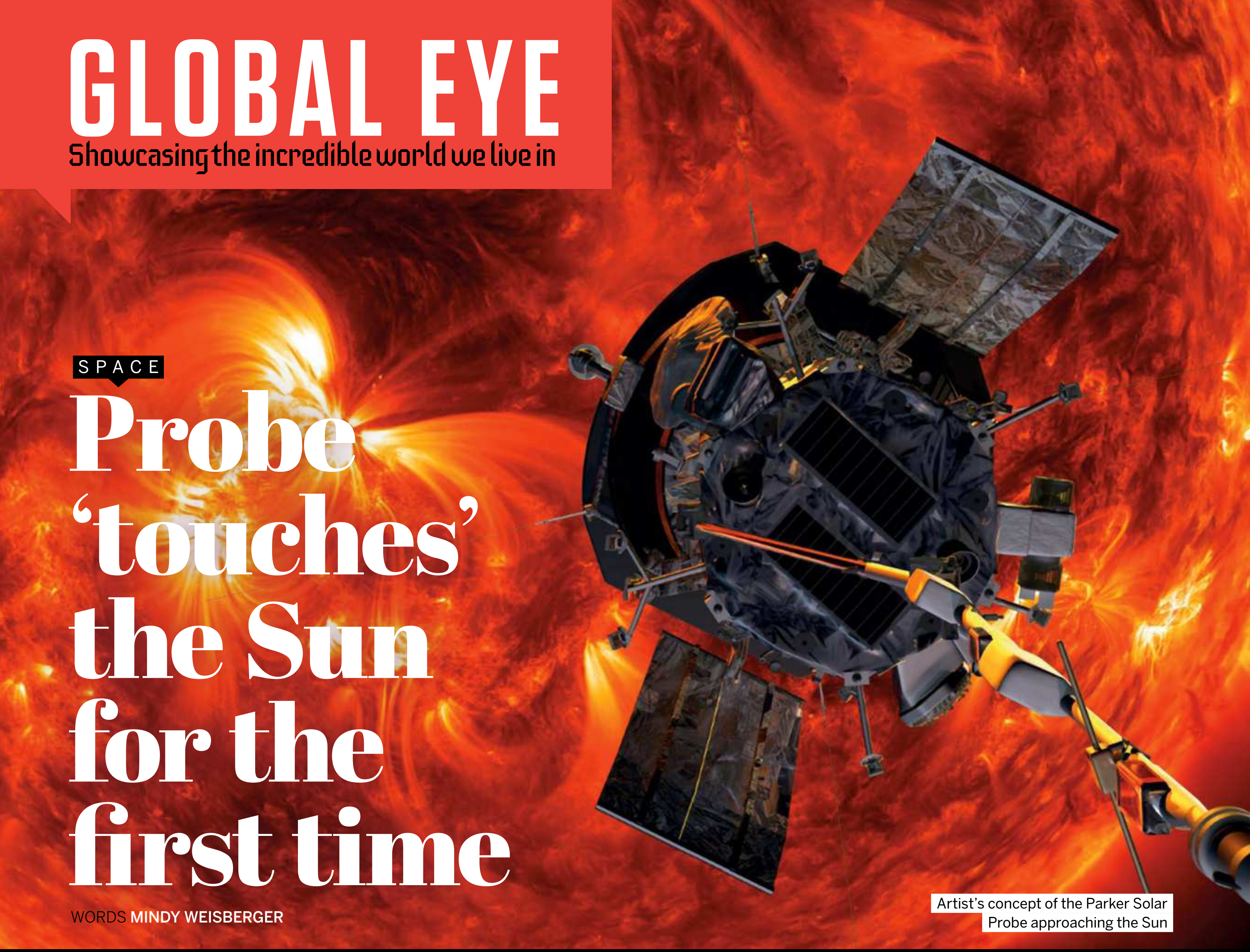


ALMA in the snow

The Atacama Large Millimeter/submillimeter Array (ALMA) sits on Chajnantor Plateau in northern Chile, and from time to time experiences snow. The white blanket of snow has been quickly carved to reveal the network of roads and pathways used to connect each of the 66 high-precision radio antennae that make up ALMA. As a collective, these telescopes are looking deep into the universe.

© ALMA (ESO/NAOJ/NRAO)



SPACE

Probe 'touches' the Sun for the first time

WORDS **MINDY WEISBERGER**

Artist's concept of the Parker Solar Probe approaching the Sun

A NASA probe has entered the Sun's atmosphere and 'touched' the blazing corona in a first for solar science. The Parker Solar Probe, which launched in 2018, conducted seven flybys of the Sun before dipping into the corona during its eighth flyby on 28 April 2021. It made three trips into the Sun's atmosphere, one of which lasted for five hours. In the upper reaches of the solar atmosphere, where temperatures average about 1 million degrees Celsius – hotter than the light-emitting surface of the Sun, which is only 5,500 degrees Celsius – the spacecraft collected atmospheric particles with a special instrument called the Solar Probe Cup. By entering and sampling the Sun's atmosphere, the Parker Solar Probe accomplished a scientific achievement akin to landing on the Moon.

"Imagine yourself sitting on a beach and staring at the ocean, wondering what lies beneath the surface. This is basically what scientists have been doing for decades, wondering what mysteries lie in the Sun's corona," said Nicola Fox, Heliophysics Division director of the Science Mission Directorate at NASA Headquarters. And just three years after the Parker Solar Probe's launch, Fox said: "We have finally arrived; humanity has touched the Sun."

The powerful solar wind, made of streaming plasma and high-energy particles, is born in the corona, but is mostly held back by the Sun's magnetic fields, which also restrain bursts of plasma that spurt from the Sun's surface. When the solar wind exceeds a certain speed and extends just past the Sun's atmosphere, a location known as the Alfvén point, it can break free of these magnetic restraints. However, scientists didn't know where exactly that point was located.

Now the Parker Solar Probe has answered that question. Prior estimates based on remote images of the corona predicted that the Alfvén point would be found approximately 4.3 million to 8.6 million miles from the solar surface. Parker detected those conditions at a distance of about 8.1 million miles above the Sun, telling researchers that it had entered the Sun's atmosphere for the first time.

The solar wind and solar flares, swift eruptions of solar radiation, can affect electrical grids and disrupt communication networks on Earth, and the new data from the probe provides an unprecedented glimpse into these solar events. A heat shield protects most of the probe from the Sun, but the Solar Probe Cup had to extend beyond that protection in order to sample the corona. Engineers constructed the cup from materials with very high melting points – sapphire, tungsten, molybdenum and niobium – so that it could function under the extreme heat.

When the cup is exposed and making its measurements, "it's literally red-hot, with parts of the instrument at more than 1,000 degrees Celsius, and glowing red-orange," said astrophysicist Anthony Case, the instrument scientist for the Solar Probe Cup. Data collected by the Parker Solar Probe in the corona reveals the Sun as it's never been seen before, which will help scientists to better understand the roiling forces that generate the enormous quantities of energy powering our Sun and other stars.

Comet Leonard, which was discovered in January 2021

SPACE

COMET LEONARD'S METEOR SHOWER ON VENUS

WORDS **ELIZABETH HOWELL**

Comet Leonard may be sparking meteor showers on Venus this weekend during a relatively close approach to the planet. Comet C/2021 A1, also known as Comet Leonard, was discovered in January 2021 by Gregory J. Leonard of the Mount Lemmon Infrared Observatory in Arizona. Its close pass of Venus this weekend gives skywatchers a marker in the evening sky to help spot the comet, which is at binocular visibility from Earth and may be just barely bright enough to be visible to the naked eye under clear, dark skies.

At Venus, though, the story is different. The orbit of the planet and the comet will come within 31,000 miles of each other, equivalent to the geosynchronous satellite orbital path above Earth. Comet Leonard is a once-in-a-lifetime comet for stargazers, as its orbit takes about 80,000 years to round the Sun. Given the thick cloud cover on Venus, watching a meteor shower at the planet would require you to be 35 to 40 miles above the surface, where the temperature and pressure are somewhat similar to Earth. Recent research suggests that the best scenario for a meteor shower occurs as Venus goes through the comet's trail, but it would require very high activity from the comet.

ANIMALS

Super-carnivorous ichthyosaur discovered

WORDS **STEPHANIE PAPPAS**

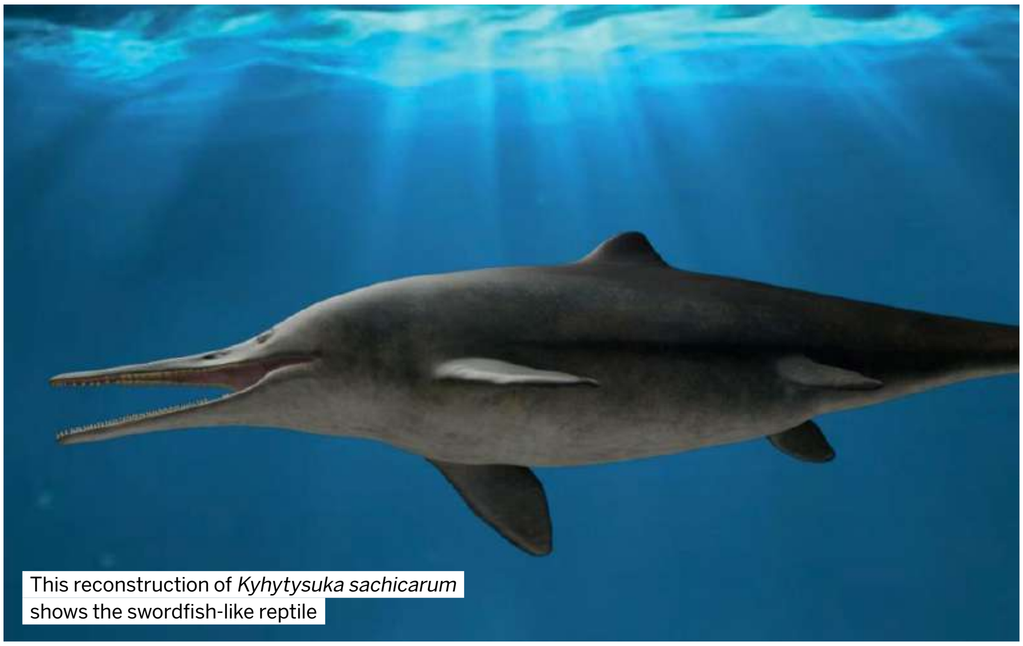
You wouldn't want to meet an ichthyosaur while taking a dip in the early Cretaceous seas. That goes double for *Kyhytysuka sachicarum*: this newly identified, 130-million-year-old marine reptile is now known from fossils in central Colombia and had larger, more knife-like teeth than other ichthyosaur species – and that's saying something, as ichthyosaurs are famous for their long, toothy snouts. These big teeth would have enabled *K. sachicarum* to attack large prey, such as fish and even other marine reptiles. "Whereas other ichthyosaurs had small, equally sized teeth for feeding on small prey, this new species modified its tooth sizes and spacing to build an arsenal of teeth for dispatching large prey," said palaeontologist Hans Larsson of McGill University's Redpath Museum in Montreal.

Ichthyosaurs were a large group of marine predators that first evolved during the Triassic Period around 250 million years ago from land-dwelling reptiles that returned to the sea. The last species went extinct about 90 million years ago during the late Cretaceous. With long snouts and large eyes, they looked a bit like swordfish. Most species had jaws lined with small, cone-shaped teeth that were good for snagging small prey.

The newly identified species was likely at least twice as long as an adult human, based on the size of the fossils that have been found – most of a skull and a few pieces of spine and ribs. Probable ichthyosaur fossils were first unearthed in Colombia in the 1960s, but researchers couldn't agree on the species or precisely how ichthyosaurs from the region were related to others from the same time period. "We compared this animal to other Jurassic and Cretaceous ichthyosaurs and were able to define a new type of ichthyosaurs," said Erin Maxwell of the State Museum of Natural History Stuttgart, Germany. "This shakes up the evolutionary tree of ichthyosaurs and lets us test new ideas of how they evolved."

The researchers named the new ichthyosaur species *Kyhytysuka*, meaning 'the one that cuts with something sharp' in the language of the indigenous Muisca culture of Colombia. There are other species of ichthyosaur with big teeth for catching large prey, but those species are from the early Jurassic Period, at least 44 million years earlier than *K. sachicarum*. At the end of the Jurassic, the seas underwent an extinction upheaval; deep-feeding ichthyosaur species, marine crocodiles and short-necked plesiosaurs died out. These animals were replaced by sea turtles, long-necked plesiosaurs, marine reptiles called mosasaurs that looked like a mix between a shark and a crocodile and this huge new ichthyosaur.

Did you know?
Some ichthyosaurs had large ear bones



This reconstruction of *Kyhytysuka sachicarum* shows the swordfish-like reptile

© Getty / Dirley Cortés / NASA/Johns Hopkins APL/Steve Gribben

Octopuses are one of several marine invertebrates to be recognised as sentient by changes to a new animal welfare bill

ANIMALS

Octopuses, squids and lobsters could be classed as 'sentient beings'

WORDS **HARRY BAKER**

A number of marine animals, including octopuses, squids, crabs and lobsters, will be recognised as sentient beings as part of a new law proposed by the UK government. The Animal Welfare (Sentience) Bill was first proposed in May 2021 and is currently under review. The law originally included all vertebrates, or animals with a backbone, but no invertebrates. However, on 19 November 2021, the UK government announced that two invertebrate groups, cephalopod molluscs (octopuses, squids and cuttlefish) and decapod crustaceans (crabs, lobsters, shrimp and crayfish) – will now be included on the list of sentient beings, which means their welfare will have to be considered when future government decisions are made about them.

"After reviewing over 300 scientific studies, we concluded that cephalopod molluscs and decapod crustaceans should be regarded as sentient, and should therefore be included within the scope of animal welfare law," said Jonathan Birch, a philosopher of biological sciences at the London School of Economics and Political Science. "I'm pleased to see the government implementing a central recommendation of my team's report."

Historically, it has been hard to prove sentience in animals because it is difficult to define. Sentience is the capacity of experiencing feelings, such as pain, pleasure and hunger. However, pain reception is now widely considered to be the central criterion policymakers consider when drafting new legislation on animal welfare. Being recognised as sentient means that the welfare of cephalopods and decapod crustaceans will have to be considered in any future decision-making processes. "The Animal Welfare (Sentience) Bill provides a crucial assurance that animal wellbeing is rightly considered when developing new laws," said Lord Zac Goldsmith, the UK's animal welfare minister. "The science is now clear that decapods and cephalopods can feel pain, and therefore it is only right they are covered by this vital piece of legislation."

However, the new listing will not affect existing legislation surrounding these animals. This means several questionable practices, such as selling animals to untrained handlers, transporting animals in ice-cold water and boiling animals live without stunning them and other extreme slaughter methods remain legal even for sentient animals. Researchers are now calling for these practices to be outlawed. Boiling lobsters alive without stunning them is already illegal in the US, Switzerland, Norway, Austria and New Zealand.

PLANET EARTH

HOTTEST EVER ARCTIC TEMPERATURE RECORDED

WORDS **BEN TURNER**

The highest temperature ever recorded in the Arctic has been officially confirmed by the World Meteorological Organization (WMO), sounding alarm bells about climate change. A 'Mediterranean' 38 degrees Celsius, which was recorded in the Siberian town of Verkhoyansk in June 2020, was measured at the peak of an extended heat wave. Temperatures across the region that summer averaged as much as ten degrees Celsius above normal.

"This new Arctic record is one of a series of observations that sound the alarm bells about our changing climate," said Petteri Taalas, the WMO's secretary-general. The WMO said the extreme heat was "more befitting the Mediterranean than the Arctic" and that the heat wave was a key factor in 'fuelling devastating fires, driving massive sea ice loss and playing a major role in 2020 being one of the three warmest years on record."

Siberia's wildfires were the worst since records began this year, destroying an area of more than 46 million acres of Russian forest in 2021 alone. The smoke from the enormous infernos even travelled as far as the North Pole. Verkhoyansk is situated roughly 71 miles north of the Arctic Circle, and its meteorological station has been taking temperature readings since 1885.

Siberian wildfires have been growing in intensity, with 2021's damage being the worst since records began

Scientists just broke the record for water's freezing point

PHYSICS

Water's freezing point just got lower

WORDS **ASHLY HAMER**

'Ice cold' just got even colder. By creating ice from tiny droplets only a few hundred molecules in size, researchers have pushed water's freezing point lower than ever before and changed what we know about how ice forms. Knowing how and why water transforms into ice is essential for understanding a wide range of natural processes. Climate fluctuations, cloud dynamics and the water cycle are all influenced by water-ice transformations, as are animals that live in freezing conditions.

While the rule of thumb is that water freezes at zero degrees Celsius, water can actually stay liquid over a range of chilly temperatures under certain conditions. Until now, it was believed that this range stopped at -38 degrees Celsius; any lower than that and water must freeze. But in a recent study researchers managed to keep droplets of water in a liquid state at temperatures as low as -44 degrees Celsius.

There were two keys to their breakthrough: very small droplets and a very soft surface. They began with droplets ranging from 150 nanometers, barely bigger than an influenza virus particle, to as small as two nanometers, a cluster of only 275 water molecules. This range of droplet sizes helped the researchers uncover the role of size in the transformation from water to ice. "We covered all of these ranges so that we can understand at which condition ice is going to form – which temperature, which size of the droplets," said Hadi Ghasemi, a mechanical engineering professor at the University of Houston. "And more importantly, we found that if the water droplets are covered with some soft materials, the freezing temperature can be suppressed to a really low temperature."

The soft material they used was octane, an oil that surrounded each droplet within the nanoscale pores of an anodised aluminium oxide membrane. That allowed the droplets to take on a more rounded shape with greater pressure, which the researchers say is essential for preventing ice formation at these low temperatures. Because it's basically impossible to observe the freezing process at these small scales, the researchers used measures of electrical conductance – since ice is more conductive than water – and light emitted in the infrared spectrum to catch the exact moment and temperature at which the droplets transformed from water to ice.

Did you know?
The Iñupiaq of Alaska have over 100 names for ice

They found that the smaller the droplet, the colder it had to be for ice to form – and for droplets that were ten nanometers and smaller, the rate of ice formation dropped dramatically. In the smallest droplets they measured, ice didn't form until the water had reached a bone-chilling -44 degrees Celsius. This discovery could mean big things for ice prevention on human-made materials, like those in aviation and energy systems. If water on soft surfaces takes longer to freeze, engineers could incorporate a mix of soft and hard materials into their designs to keep ice from building up on those surfaces.

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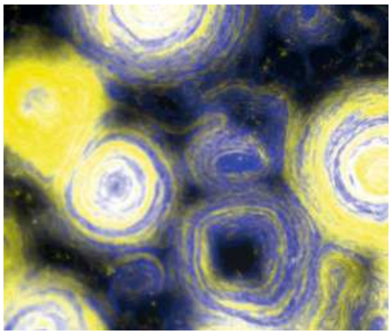
STRANGE NEWS

MUTANT BACTERIA LOOK LIKE VAN GOGH'S *STARRY NIGHT*

WORDS **HARRY BAKER**

A group of swarming bacteria just created strikingly artistic 'paintings' that are reminiscent of masterpieces by Dutch painter Vincent van Gogh. Microbiologists noticed the similarities while studying the social cooperation of predatory bacteria called *Myxococcus xanthus*. Individuals in this species are known to form cooperative swarms, in which they share resources to help overwhelm prey. Researchers were studying a pair of proteins, TraA and TraB, that allow these microbes to recognise and bond with each other. The team created mutated strains of *M. xanthus* that overexpressed the genes behind these proteins to see how they'd change.

As the mutated strains formed swarms, the clumps of conjoined cells formed swirling patterns. The researchers then digitally added different colours to distinguish each strain. Once the colour was added, the team realised the striking resemblance between the bacteria-made art and van Gogh's, especially with the blue-and-yellow image which has a striking resemblance to *The Starry Night*, one of the most famous pieces by the 19th-century painter. The discovery highlights how studying social bacteria may reveal "behaviours that also exhibit artistic beauty," said Daniel Wall, a molecular biologist at the University of Wyoming.



A strain that adheres to itself (yellow) and a strain that's non-adhesive and non-reversing (blue) created this art

ANIMALS

Newfound millipede breaks a world record

WORDS **CAMERON DUKE**

A newfound species of millipede has more legs than any other creature on the planet, a mind-boggling 1,300 of them. The leggy critters live deep below Earth's surface and are the only known millipedes to live up to their name. "The word 'millipede' has always been a bit of a misnomer," said Paul Marek, an entomologist at Virginia Tech University. All other known millipedes sport far fewer legs than their name implies, with many species having fewer than 100 legs. Until now, the record holder was a species called *Illacme plenipes*, a deep-soil dweller known to have as many as 750 legs. But the newfound species, *Eumilipes persephone* – named after Persephone, the daughter of Zeus who was taken by Hades to the underworld – is the leggiest known animal on the planet. One specimen Marek analysed has 1,306 legs, which smashes the current record.

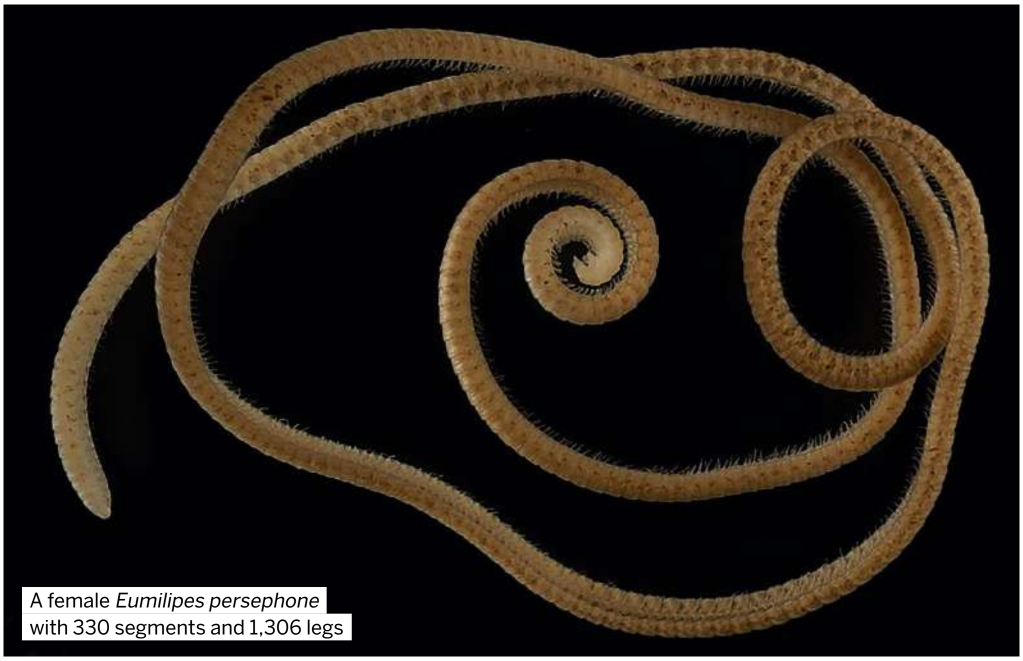
The new world record holder is a pale, eyeless creature with a long, threadlike body that's nearly 100 times longer than it is wide. Its cone-shaped head has enormous antennae for navigating a dark world governed by pheromones and a beak that's optimised for feeding on fungi. The legs are difficult to count because the animal tends to coil like a little watch spring. The copious collection of legs also provides a hint about these creatures' life span. "I suspect these animals are extremely long-lived," said Marek. Millipedes grow steadily, adding body segments, called rings, throughout their lives. Entomologists can count these segments like tree rings to establish relative ages between individuals of the same species.

This species was discovered 60 metres below Earth's surface in a relatively unexplored environment built from banded-iron formations and volcanic rock. The creatures were first spotted in a region of Western Australia known as the Goldfields, a nexus for mineral extraction.

Companies prospecting for nickel and cobalt bore deep, narrow holes between 20 and 100 metres deep. "Some time ago, entomologists from Western Australia came up with the idea to sample these boreholes" because they provide the perfect opportunity to peer into subterranean ecosystems. By lowering cups of leaf litter and other detritus to certain depths, waiting for a few weeks and retrieving them, we can sample the wide variety of life thriving far below our feet.

The new find shows "there are a lot more discoveries to be made," Marek said. Though species that live so deep beneath our feet can seem removed from life on the surface, these ecosystems play an important ecological role that's tied to surface life. Subterranean decomposers help recycle nutrients that surface life relies on, and the deep soil layers these animals live in filter toxins from our water.

Did you know?
Most millipedes have two pairs of legs per segment



A female *Eumilipes persephone* with 330 segments and 1,306 legs

HISTORY

Epic sea level rise drove Vikings out of Greenland

WORDS **MINDY WEISBERGER**

The Vikings are remembered as fierce fighters, but even these mighty warriors were no match for climate change. Scientists recently found that ice sheet growth and sea level rise led to massive coastal flooding that inundated Norse farms and ultimately drove the Vikings out of Greenland in the 15th century.

The Vikings first established a foothold in southern Greenland around 985 CE with the arrival of Erik Thorvaldsson, also known as Erik the Red, a Norwegian-born explorer who sailed to Greenland after being exiled from Iceland. Other Viking settlers soon followed, forming communities in Eystribyggð (Eastern Settlement) and Vestribyggð (Western Settlement) that thrived for centuries. At the time of the Vikings' arrival, Greenland was already inhabited by people of the Dorset culture, an indigenous group that preceded the arrival of the Inuit people in the Arctic.

Around the 15th century, signs of Norse habitation in the region vanished from the archaeological record. Researchers previously suggested that factors such as climate change and economic shifts likely led the Vikings to abandon Greenland. Now, new findings show that rising seas played a key role by submerging miles of coastline.

Between the 14th and 19th centuries, Europe and North America experienced a period of significantly cooler temperatures, known as the Little Ice Age. Under these chilly conditions, the Greenland ice sheet, a vast blanket of ice covering most of Greenland, would have become even bigger.

As the ice sheet advanced, its increasing heaviness weighed down the substrate underneath, making coastal areas more prone to flooding. At the same time, the increased gravitational attraction between the expanding ice sheet and large masses of sea ice pushed more seawater over Greenland's coast. These two processes could have driven widespread flooding along the coastline, "exactly where the Vikings were settled," said Marisa Julia Borreggine, a doctoral candidate in the Department of Earth and Planetary Sciences at Harvard University.

Recently, scientists modelled estimated ice growth in southwestern Greenland over the 400-year period of Norse occupation, adding those calculations to a model showing sea level rise during that time. They then analysed maps of known Viking sites to see how their findings lined up with archaeological evidence marking the end of a Viking presence in Greenland. Their models showed that from about 1000 to 1400 CE, rising seas around Greenland would have flooded Viking settlements by as much as five metres, affecting about 54 square miles of coastal land. This flooding would have submerged land that the Vikings used for farming and as grazing pastures for their cattle.

However, sea level rise was probably not the only reason the Vikings left Greenland. Other types of challenges can cause even long-standing communities to collapse, and a perfect storm of external pressures, such as climate change, social unrest and resource depletion may have spurred the Vikings to abandon their settlements for good.

"A combination of climate and environmental changes, the shifting resource landscape, the flux of supply and demand of exclusive products for the foreign market and interactions with Inuits in the north all could have contributed to this out-migration," said Borreggine. "Likely a combination of these factors led to the Norse migration out of Greenland and further west."

Ruins of a church in Hvalsey, a Norse settlement in Greenland. Vikings built the structure around the 14th century

© Getty / D. Wall/University of Wyoming / wiki: Paul E. Marek, Bruno A. Buzatto, William A. Shear, Jackson C. Means, Dennis G. Black, Mark S. Harvey, Juanita Rodriguez, Scientific Reports

More than 200 cane toads have been captured by researchers

ANIMALS

Toxic cane toads invade Taiwan

WORDS HARRY BAKER

Conservationists in Taiwan are racing to contain an invasion of non-native and highly toxic toads before the warty amphibians cause widespread damage to their new ecosystem. The cane toad (*Rhinella marina*) is a highly toxic species of toad native to the Americas, from the Central Amazon in Peru to the Rio Grande Valley in Texas. However, the species was also introduced across the globe in the early 20th century to various places, including the Caribbean, Australia and large parts of the Pacific. Adult cane toads range from 9 to 15 centimetres in length and have yellow and brown skin covered with irregular warts. When threatened, cane toads release a milky-white toxin from their skin known as bufotoxin, which oozes from glands behind their eyes and is lethal to most animals.

Researchers in Taiwan learned of a possible cane toad invasion at a farm in a small town in Taiwan's central mountain range after a local resident shared photos of a cane toad online. After seeing the photo, researchers from the Taiwan Amphibian Conservation Society immediately paid a visit to the farm to investigate. "A speedy and massive search operation is crucial when cane toads are first discovered," Lin Chun-Fu, an amphibian scientist at Taiwan's Endemic Species Research Institute, stated. They reproduce rapidly and "they have no natural enemies here in Taiwan," he added.

When the researchers arrived at the farm, they found 27 toads in the immediate vicinity. Since then they have captured more than 200 cane toads in the area surrounding the town. Cane toads are an extremely successful invasive species. They are only native to 14 countries, but are now found in more than 40 countries across the world, landing them a spot on the list of the 100 worst invasive species overseen by the Invasive Species Specialist Group, an international advisory body of scientists and policy experts.

Females can lay up to 30,000 eggs at a time and can mate year-round. Unlike other toads, which are exclusively predators, cane toads can also act as scavengers. Without natural predators, their numbers quickly explode, and they can seriously damage ecosystems where they're introduced.

Researchers believe that a black market pet trade could have caused the recent Taiwan invasion. Cane toads have long been a popular pet in Taiwan, and are also used in traditional medicines. But in 2016 the Taiwanese government banned the import of cane toads, which led people to breed and sell them illegally. The leading theory is that the invasive cane toads either escaped or were abandoned by one of these black market traders. The researchers are now hopeful that they have contained the invasion, but it's too early to tell for certain. "Next spring during mating season is when we truly know for sure if we have contained it," Yi-Ju Yang, a toad expert at National Dong Hwa University, said.

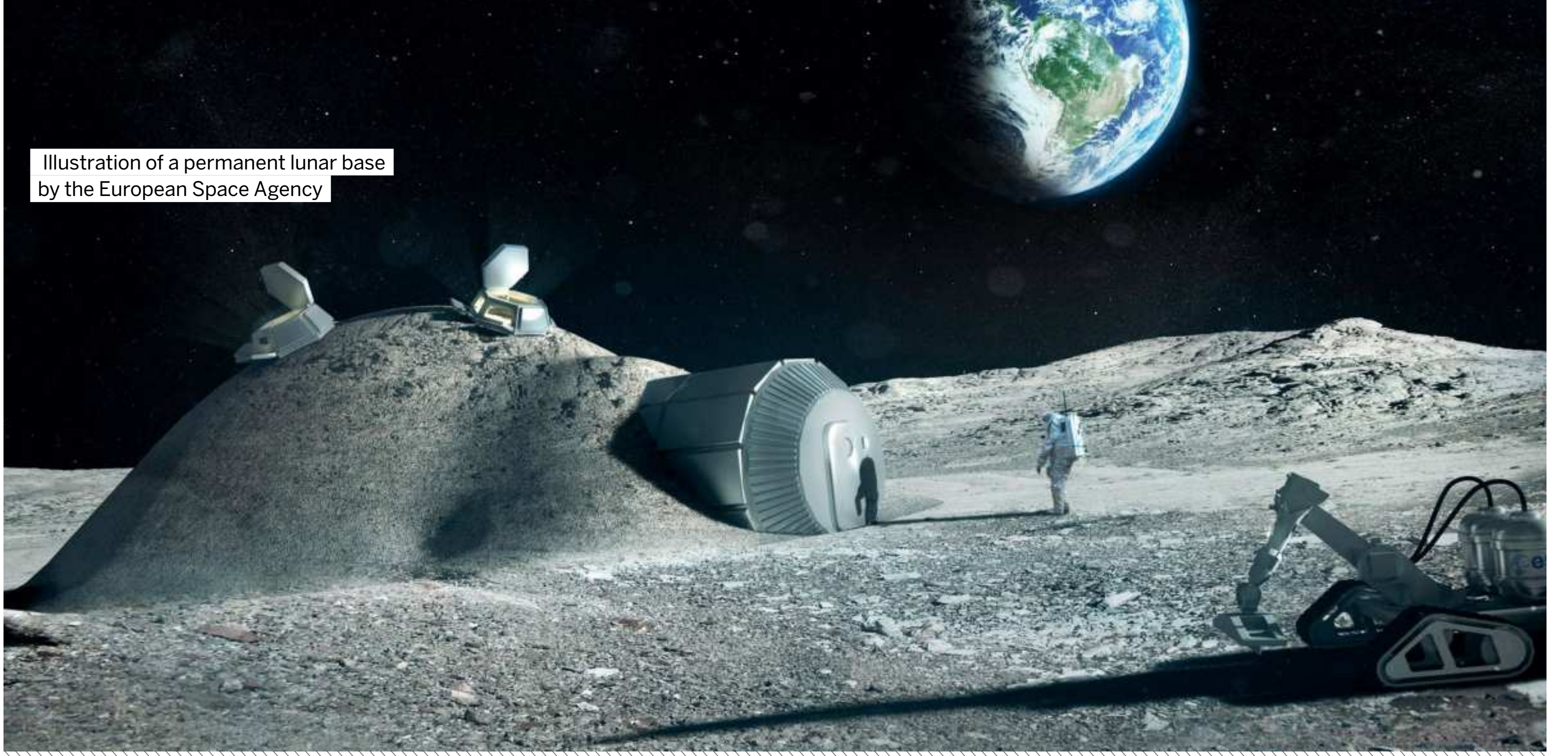


Illustration of a permanent lunar base by the European Space Agency

SPACE

NASA plans a lunar nuclear power plant

WORDS **BRANDON SPECKTOR**

The Department of Energy's Idaho National Laboratory (INL) is teaming up with NASA to put a "durable, high-power, Sun-independent" fission reactor on the Moon within the next ten years. The two agencies are currently seeking proposals from outside partners to get this lofty project started, with a submission deadline of 19 February 2022. This hypothetical reactor would help turn the Moon into an extraterrestrial base for human space exploration, including future manned missions to Mars. "Plentiful energy will be key to future space exploration," said Jim Reuter, associate administrator for NASA's Space Technology Mission Directorate in Washington DC, said. "I expect fission surface power systems to greatly benefit our plans for power architectures for the Moon and Mars and even drive innovation for uses here on Earth."

The call for proposals comes with some basic guidelines. The proposed reactor must be a uranium-powered fission reactor – an apparatus that can split heavy atomic nuclei into lighter nuclei, releasing energy as a by-product. The reactor must weigh no more than 6,000 kilograms and fit into a four-by-six-metre rocket.

The nuclear reactor will be assembled on Earth, then launched to the Moon, where it must provide 40 kilowatts of continuous electric power for ten years. The reactor must also have temperature controls to keep the device cool. The request for proposals comes while NASA begins ramping up its Artemis program, which aims to create a sustainable human presence on the Moon by the end of the decade. The program, which plans to return human astronauts to the Moon for the first time since 1972, is estimated to cost around $93 billion (around £70 billion).

STRANGE NEWS

US NUCLEAR SUBMARINE COLLIDES WITH UNDERWATER MOUNTAIN

WORDS **HARRY BAKER**

A nuclear-powered submarine that ran aground in the South China Sea last month collided with an uncharted seamount. The USS Connecticut, a Seawolf-class fast-attack submarine, collided with an unknown object in international waters on 2 October, causing minor to moderate injuries to 11 crew members. The damaged submarine surfaced and made it to a port in Guam unassisted. The Navy hasn't disclosed the full extent of the damage, and all the Navy said about the incident at the time was that "it wasn't another submarine" that had collided with the vessel. But a report released by the US Seventh Fleet on 1 November 2021 has "determined that Connecticut grounded on an uncharted seamount."

Seamounts, underwater mountains, are remnants of extinct underwater volcanoes. The majority are cone-shaped, but some – known as guyots – have large, flat summits. Seamounts are biological hotspots for marine life because their steep sides encourage the upwelling of nutrients from the deep sea and provide a place for sessile organisms, like corals and sponges, to settle and grow. Over 100,000 seamounts of at least 1,000 metres may dot the ocean floor, but scientists have mapped less than 0.1 per cent of them. In 2005 the USS San Francisco, another nuclear-powered submarine, hit an uncharted seamount in Guam at a top speed of 30 knots, which injured almost all of its 137-person crew and killed one.

Submariners standing on top of the USS Connecticut in the water at Naval Base Kitsap

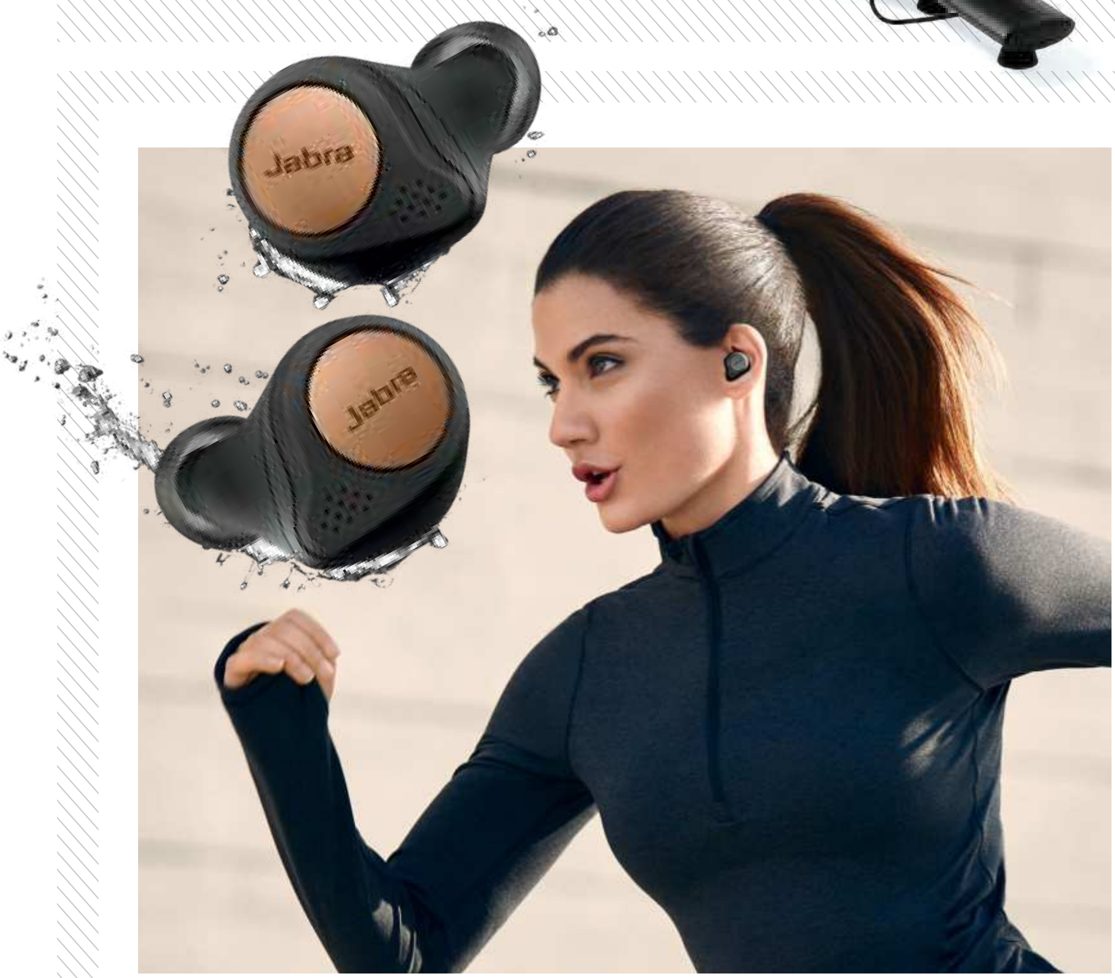
© Getty / ESA

PELOTON BIKE

WWW.ONEPELOTON.COM £1,350 / $1,495

With daily live classes and thousands of on-demand workouts, the Peloton Bike makes it super easy to stick to a regular fitness program. Recreating a spin studio experience has never been easier, with engaging instructors and on- and off-bike training to keep you motivated. The Peloton Bike features a sound system and a 3.5-millimetre headphone jack, perfect for those who want to work out without disturbing those around them with Peloton's famous live classes. This exercise bike also features Bluetooth 4.0 connectivity, a five-megapixel front-facing camera and a built-in microphone. These aren't common exercise bike features and are one of the premium perks you pay for as part of the Peloton experience.

"The Peloton Bike makes it super easy to stick to a regular fitness program"



JABRA ELITE ACTIVE 75T

WWW.JABRA.COM
£179.99 / $179.99

These comfortable magnetic earphones have a secure fit thanks to their special grip coating, which is designed to keep the buds in place as you run. If you want to immerse yourself in your music as you're running, these headphones also have active noise cancellation. You can use the Jabra Sound app to flip between noise cancellation and 'hear through' mode. Battery life sits at 5.5 hours, which isn't as long as some other models. However, the small portable charge case means that you'll have up to 24 hours of battery life altogether. Compatible with Siri, Alexa and Google Assistant, the earbuds have four microphones embedded, designed to enable you to take high-quality calls and avoid the annoyance of not being able to hear the person on the other end.

GARMIN FENIX 6X PRO SOLAR EDITION

WWW.GARMIN.COM £849.99 / $949.99

The 6X Pro Solar represents the best that Garmin can put into a fitness watch, with detailed insights on how to improve your workouts across different terrain types and intricate features such as preloaded ski maps for thousands of slopes around the world. The crowning jewel of this watch, the solar panel on the face, is a new addition to Garmin's line, designed to help those struggling to get through a multi-day ultra-marathon eke out a few more moments of battery life. Underneath the intriguing new features is a powerful watch with extensive exercise tracking. There's a whole host of workouts you can track, from running and kayaking to parachuting and bouldering. It's got a rugged and large frame which isn't that pretty, but you know it will survive if you fall down a rocky waterfall.

10:10
SOLAR INPUT
Last 6 Hours

WELLY TRAVELER INFUSING WATER BOTTLE

WWW.WELLYBOTTLE.COM FROM $30 (APPROX. $22.50)

If you don't like drinking plain tap water, the Welly Traveler will appeal. Made from stainless steel, natural bamboo, silicone and BPA-free plastic, this option also includes a removable infuser so you can naturally flavour water with fruit or herbs. Drinks are kept cool for up to 24 hours thanks to triple-walled vacuum insulation, and the bottle's sweat-free exterior stops it from slipping out of your hands. A loop cap that unscrews comes as standard, or there's the option to buy an insulated flip cap if that's your preferred lid for drinking. There's an aesthetically pleasing range of bottle designs to choose from, including terrazzo and leopard print, and it's also available in 0.35 to 0.80 litre sizes. Plus, your purchase will support a good cause, with Welly donating one per cent of bottle sales to clean water projects around the world.

WATERROWER A1 **WWW.WATERROWER.COM £849 / $895**

If you want a rower with a wow factor that looks fabulous in your living room, this is the one for you. The combination of the drum filled with water and the sleek wooden design means it's a seriously good-looking machine, and some of the more expensive, solid-wood WaterRower models are even more chic. WaterRower aims to recreate the experience of rowing on the water, and although serious rowers might challenge this, there's no denying that it provides a comfortable, smooth row, and its fans rave about the signature whooshing sound it makes. The downside of rowing in water is that you can't adjust the resistance as you can with air and magnetic rowers. It also means the machine is heavy, which may be a factor for home use. The monitor is pretty basic, so if it's high-tech graphics or serious data you're after, this may not be the machine for you.

© Jabra / Welly / Garmin / Peloton

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Britain's worst mining disaster

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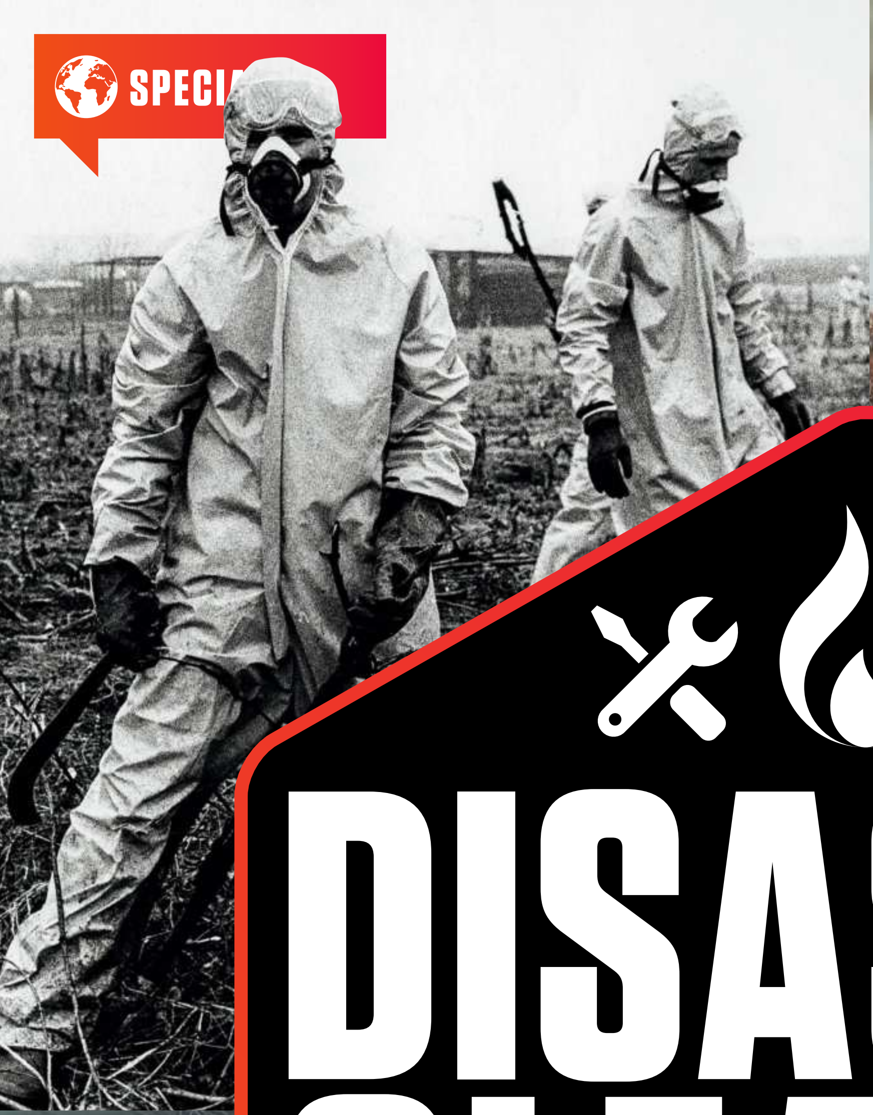
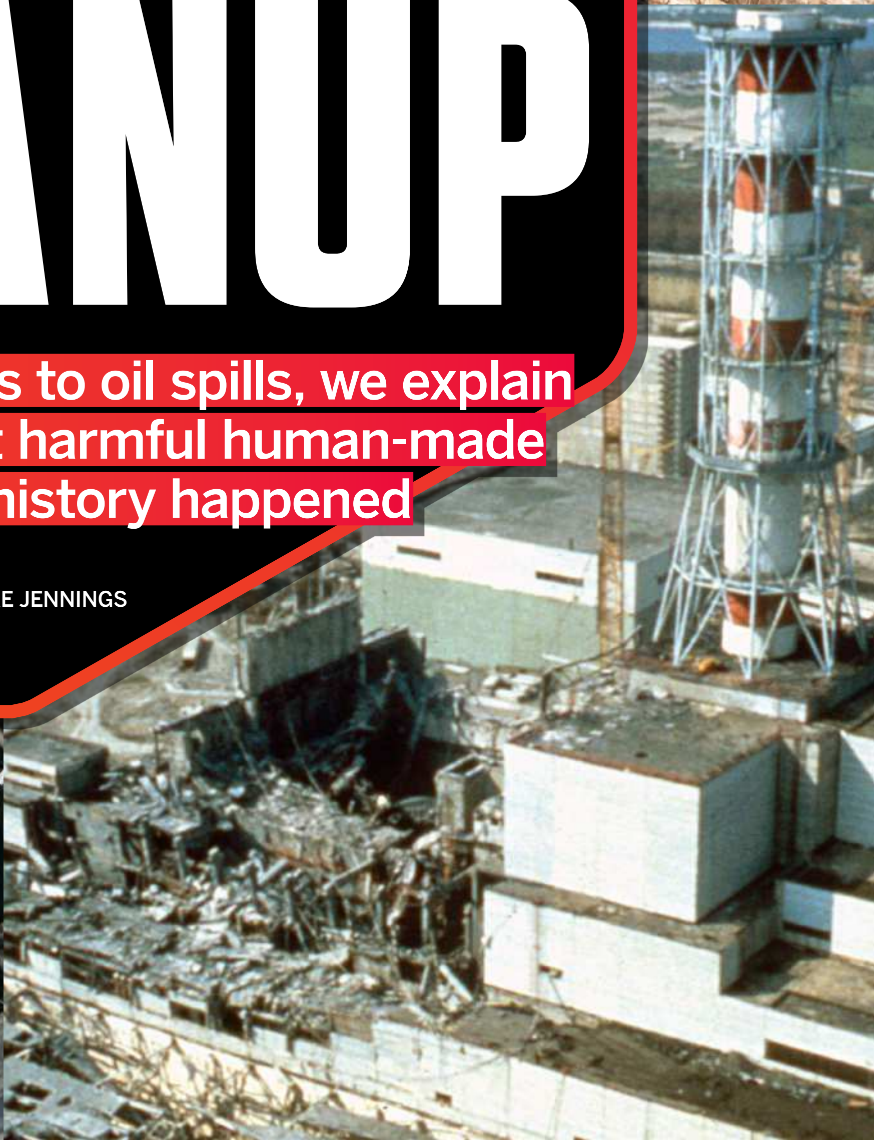


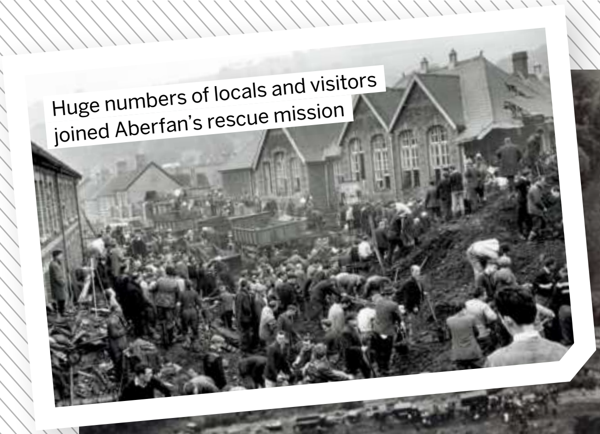
DISASTER CLEANUP

From nuclear explosions to oil spills, we explain how some of the most harmful human-made catastrophes in history happened

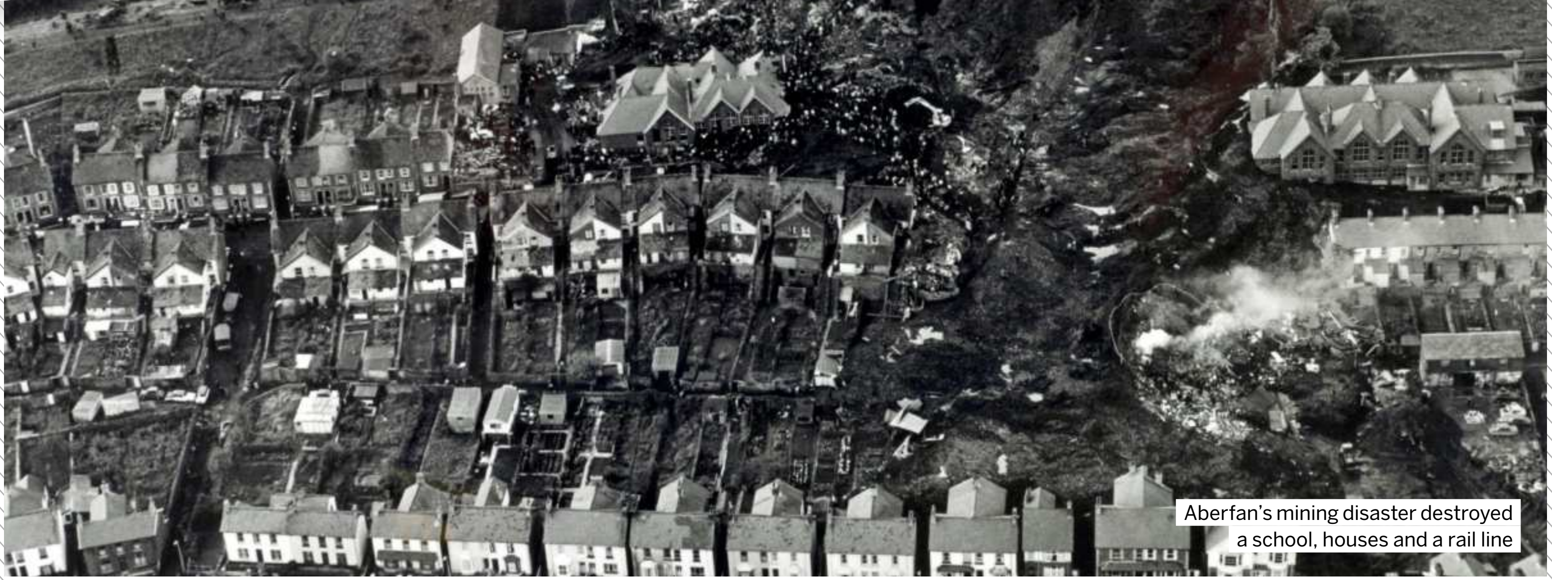
WORDS **MIKE JENNINGS**



DID YOU KNOW? The spoil tip that collapsed in Aberfan contained 227,000 cubic metres of material and was 34 metres tall



Huge numbers of locals and visitors joined Aberfan's rescue mission



Aberfan's mining disaster destroyed a school, houses and a rail line

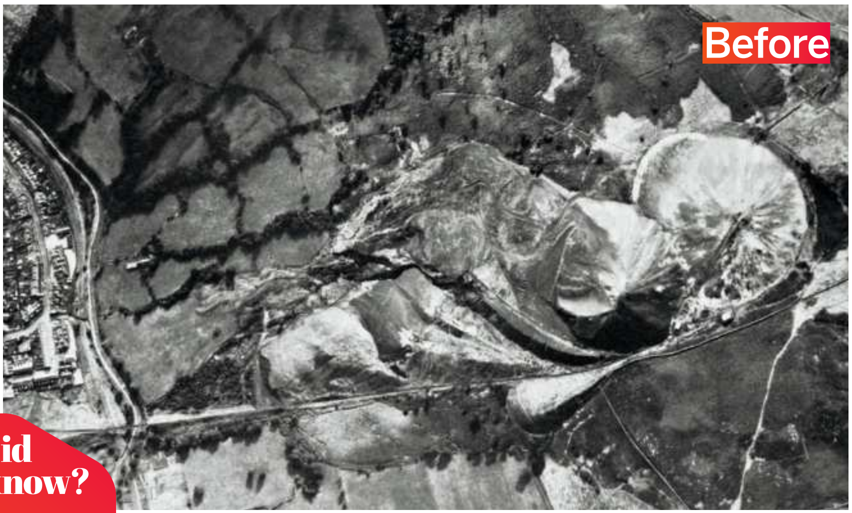
Britain's worst mining disaster

Big disasters don't often happen in the UK, and that made the Aberfan colliery slip even more shocking. The Welsh village of Aberfan grew up around a nearby coal mine, which was established back in 1869. By 1966 the settlement had grown, hosting a population of around 5,000, and the village was surrounded by seven huge spoil piles – waste material from mining. That's not necessarily a problem, but in October 1966 the village was hit by more than 17 centimetres of rainfall, and that caused the seventh spoil pile to subside. At 09:15 on 21 October 1966, a vast quantity of saturated debris broke free from the pile and travelled towards the village at speeds between 11 and 21 miles per hour and in waves up to nine metres high.

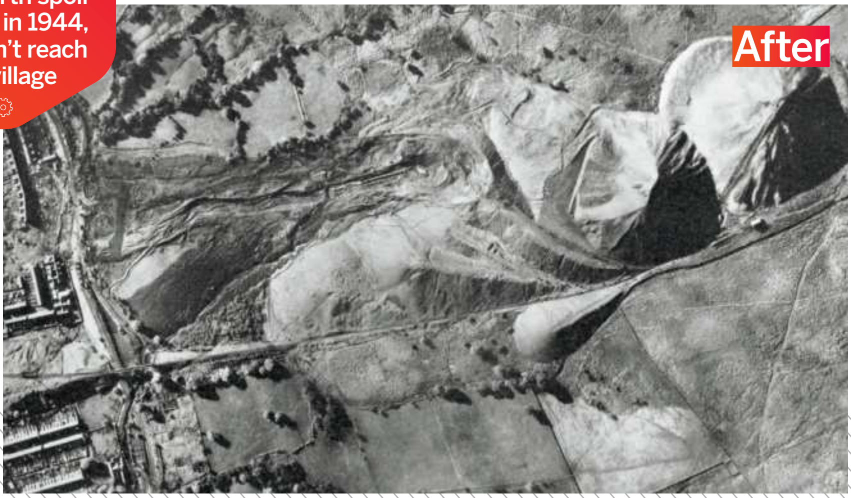
The result was devastating: the ensuing avalanche of fast-moving material demolished a primary school and damaged a nearby secondary school, as well as 18 nearby houses. The village was engulfed by tonnes of dusty and stony black coal mining waste. Thousands of volunteers travelled to Aberfan to aid rescue efforts, and the prime minister and queen both visited in the days following the incident. The Aberfan disaster remains one of the UK's worst mining incidents.

Did you know?

The fourth spoil pile slid in 1944, but didn't reach the village



Before



After

© UKGOV / Getty

The vast explosion at Chernobyl pumped nuclear material into the atmosphere

A nuclear experiment with explosive results

The explosion at Chernobyl Nuclear Power Plant in what was then Soviet Russia is one of the world's most infamous human-made disasters – and with good reason. It started innocently enough, with engineers performing a routine experiment to find out if the plant's emergency water cooling would still work during a power outage.

The test had been carried out previously, but on this occasion there was a power surge and engineers couldn't shut down Chernobyl's nuclear reactors. Steam built up in one reactor, the roof was blown off, the nuclear core was exposed and radioactive material was released into the atmosphere. Many workers and firefighters were hospitalised and 28 people passed away from acute radiation exposure. It took nearly two weeks and military intervention to extinguish the fires. Crucially, it took more than a day for the 50,000 residents of nearby Pripyat to be evacuated. Following this, the government established a 19-mile 'exclusion zone' and built a containment dome over the top of the site. In the years following the incident, studies estimate that thousands of people have developed cancer because of the radiation. It's one of the most expensive disasters in history, too, and it's estimated that containment and clean-up efforts will continue until 2065.

> "The explosion at Chernobyl is one of the most infamous human-made disasters"

Toxic cloud

The story of Libby, Montana, is typically American: settlers arrived in the 1800s and the town expanded thanks to mine and railroad construction. In 1919, the discovery of a mineral called vermiculite changed Libby's fate. Vermiculite has many uses, from gardening to car parts, and the mine in Libby was producing 80 per cent of the world's supply by 1963. But some vermiculite contains asbestos, a dangerous substance that can cause a huge range of lung issues.

The vermiculite in Libby did. The mining company knew about its dangerous side effects, but they didn't tell anyone, and people in Libby used the mine's waste products for building and landscaping, including in school projects and ice rinks. As a result, nearly ten per cent of the town's population suffered from asbestos-related illnesses. These people weren't always miners – the asbestos fibres that cause health problems are easy to pass to others.

Libby had effectively spent decades operating under a toxic cloud. The mine was closed in 1990, but the town's issues didn't become well known until 1999, and in 2009 the US government declared an emergency in Libby to clean up the town. By then, though, it was too late. Hundreds of people have passed away from asbestos-related health issues, thousands more have experienced illness and new deaths and diseases were still being reported as late as 2018 due to the long-term effects of living with asbestos.

Deadly chemical leak

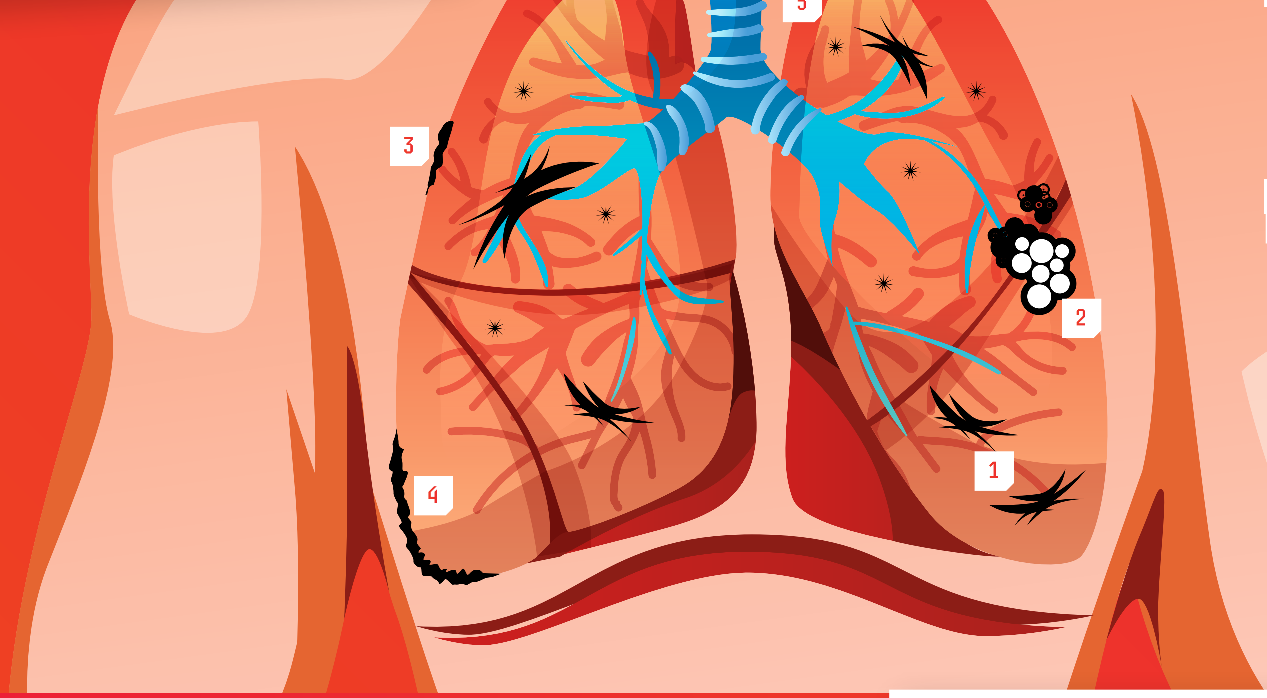
This industrial accident took place at a chemical plant north of Milan in Italy. On Saturday 10 July 1976, the factory was producing a chemical called 2,4,5-Trichlorophenol, which has been used as a chemical weapon and in weed killers. On that day, however, a chain reaction ruptured the reactor. That caused six tonnes of toxic chemicals to burst into the sky. The cloud settled over seven square miles of the surrounding area, including the town of Seveso. Many people were hospitalised with skin inflammations, hundreds of residents suffered from skin conditions and huge areas of land were evacuated.

Special measures were needed to clean up Seveso's chemical leak

DID YOU KNOW? Russia didn't raise the alarm about Chernobyl – it was Swedish workers who spotted high radiation levels

THE RISKS OF ASBESTOS

Deadly asbestos fibres can cause serious health problems for decades, including these five issues



1 ASBESTOSIS
Asbestos fibres can scar lung tissue, which stops lungs expanding properly. Sufferers struggle to breathe.

2 LUNG CANCER
Mesothelioma is a cancer linked to asbestos exposure. It develops in the lungs, but quickly spreads to other organs.

3 PLEURAL THICKENING
The pleura is a thin layer of tissue around the lungs. Asbestos thickens this lining, causing breathing difficulties.

4 PLEURAL PLAQUE
Fibres don't just thicken the pleura. They also cause scarring which can harden over time, creating pain when breathing.

5 ENLARGING HEART
Breathing and blood flow difficulties mean your heart works harder. Its muscles can become thicker, which can cause chest pains.

STOP
POSTED
ASBESTOS
HAZARD
NO TRESPASSING
DANGER
AUTHORIZED
PERSONNEL
ONLY
BEYOND
THIS POINT

Libby's mine is now sealed

Special crews removed asbestos from thousands of contaminated buildings

CLEANING UP LIBBY

The US government's Environmental Protection Agency investigated more than 8,000 properties in Libby and had to decontaminate more than 3,000 different sites where asbestos was used in construction. More than 765,000 cubic metres of material was replaced over the course of the clean-up project, and more than half a billion dollars was spent to decontaminate the town. Contaminated material is now stored safely at the site of the former mine, and the project has only begun to slow down in the past couple of years – that's no wonder, as it's been the biggest asbestos clean-up project in US history.

Libby was so contaminated that thousands of buildings needed to undergo asbestos removal

© Alamy / Getty

Devastating ocean spill

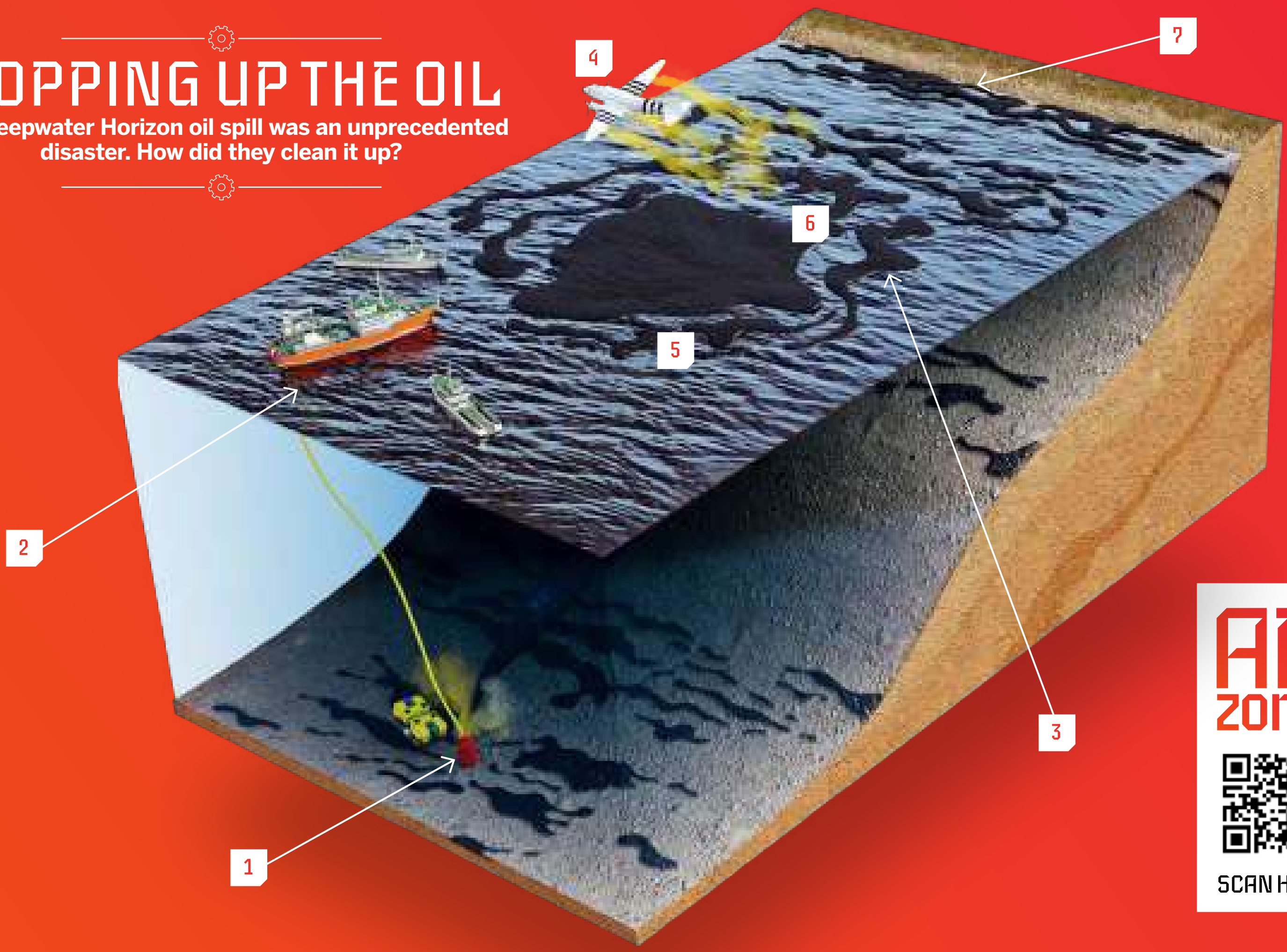
Satellite imagery shows the extent of the Deepwater Horizon oil spill

Oil spills are among the most visible disasters of our time, and 2010's Deepwater Horizon incident is reputed to be the largest marine oil spill in history. The name comes from the drilling apparatus at the centre of the incident. The Deepwater Horizon oil rig was a floating platform that was drilling an exploratory oil well 5,600 metres below sea level in the Gulf of Mexico. That wasn't a problem, and the rig was operating well within its limits. But on 20 April 2010, methane gas from the underwater well expanded and rose into the drilling rig, where it ignited and exploded. The explosion quickly engulfed the entire drilling platform, forcing 94 crew members to be evacuated. Two days later, the rig had sunk.

A vast oil slick emerged from the underwater well and began to spread at the site. BP, the company that had contracted the Deepwater Horizon ship for exploratory drilling, tried to halt the leak with remote-controlled underwater vehicles, a 125-tonne containment dome and by drilling a secondary well, but the oil flowed for 87 days. It's estimated that 955 million litres of oil were leaked from the underwater well and that the spill directly affected 70,000 square miles of ocean in the Gulf of Mexico. Eventually, the oil was contained, then either dispersed or cleaned up using several different methods and thousands of volunteers. But by then the environmental impact was being felt on a global scale: the Deepwater Horizon spill killed millions of animals, and the incident affected wildlife and ecosystems across several US states and beyond.

MOPPING UP THE OIL

The Deepwater Horizon oil spill was an unprecedented disaster. How did they clean it up?



AR zone

SCAN HERE

1 INITIAL EFFORTS BP tried to close valves to stop the oil and placed a 125-tonne dome over the leak. Neither idea worked.

2 PUMPING AWAY Huge quantities of oil was pumped onto ships, but this method collected less than half of the spill.

3 BOOM DEVICES Vast containment devices called booms were stretched over 2,550 miles of ocean to stop the spread of oil.

4 PLANE DISPATCH Planes flew over the spill to release strong chemical detergents that can help to break down oil and disperse the slick.

5 FIRE IN THE HOLE Eventually, controlled fires burned away some of the oil, but only five per cent of it was removed using this method.

6 SKIM AND ABSORB Machines called skimmers scooped up oil from the sea, and special materials absorbed and broke down the oil.

7 ON SHORE Shore clean-up operations involved sifting sand, removing tar, washing animals on beaches and pumping oil out of fragile marshland ecosystems.

DID YOU KNOW? Some of the mud from the volcano in Sidoarjo can be as hot as 60 degrees Celsius

5 OIL SPILL IMPACTS

1 WILDLIFE IS IMMEDIATELY DEVASTATED
Oil spills quickly kill marine wildlife, including fish and mammals. And it's not just birds that wash up on beaches – everything suffers, from tiny plankton to dolphins with blocked blowholes.

2 FOOD CHAIN DISRUPTION
Because oil kills so much wildlife, every animal's food supply is affected. With a spill as large as Deepwater Horizon, this means that there's an impact on a global scale.

3 HABITATS ARE DESTROYED
Oil in underwater sediment can affect the food and breeding grounds of marine animals, and beaches getting ruined means that animals like turtles can't find anywhere to lay their eggs.

4 LONG-TERM PROBLEMS
Oil is a toxic substance that can hang around in the body and cause internal problems for years. So sadly, wildlife may continue to suffer for a long time after a major oil spill.

5 HUMAN IMPACT
Many people depend on coastal areas for their livelihood. Whether it's from fishing or tourism, destruction of these regions can ruin or severely impact people's lifestyles and prospects.

Did you know?
The Jilin blasts shattered windows 200 metres away

Water supplies were disrupted for days after toxic chemicals leaked into rivers

Toxic tap water

This incident took place in the Chinese city of Jilin in November 2005, and saw a series of explosions at a petrochemical plant. In the immediate aftermath of the blasts, more than 10,000 people were evacuated from the local area. That's bad enough, but it's not the full story. The explosions released 100 tonnes of pollutants into the Songhua River, and that was a big deal because several large cities depend on that river for their water supply. Water was cut off for several days while the water supplies were cleaned up, and water had to be transported from unaffected cities to help people cope.

Candlelit vigils commemorate the deaths of people who passed away in the Bhopal gas leak

The factory in Bhopal still lies derelict today, 37 years after the incident

Poison gas leak

On 2 December 1984, there was a gas leak at a pesticide plant in Bhopal, India. It was caused by malfunctioning safety systems, and a runaway pressure increase saw 40 tonnes of a chemical called methyl isocyanate leak into the atmosphere. That's a huge amount of toxic material, and the plant was surrounded by densely packed housing, so more than 500,000 people were exposed to the toxic cloud. The people living around the plant were not informed quickly, and hospital staff were given conflicting information about the situation. Many people living in the area suffered from coughing, eye irritation, burns, breathlessness, vomiting and worse. Thousands of animals suffered, too.

Longer term studies since the accident have confirmed that the health of many local people is still affected by the incident. Some effort has been made to clean up the soil and water around the plant, but the area is still contaminated today.

© NASA / Getty / Illustration by Nicholas Forder

California wildfires

Climate change has seen wildfires become a far more common threat, and one summer saw huge areas of California affected by some of the worst fires in recent memory. Over 8,500 fires raged across the state in 2018, destroying more than 24,000 buildings and burning 2 million acres of land. Most of the California fires took place in July and August. The years that preceded the fires saw an increase in temperature due to climate change, and that killed plenty of trees in California. Those dead, dry trees provide ample fuel for fires to spread. Scientists predict that this kind of disaster is only going to become more common because of climate change.

Thousands of firefighters struggled to contain unprecedented blazes that lasted for months

Did you know?

California's biggest fire covered 459,123 acres

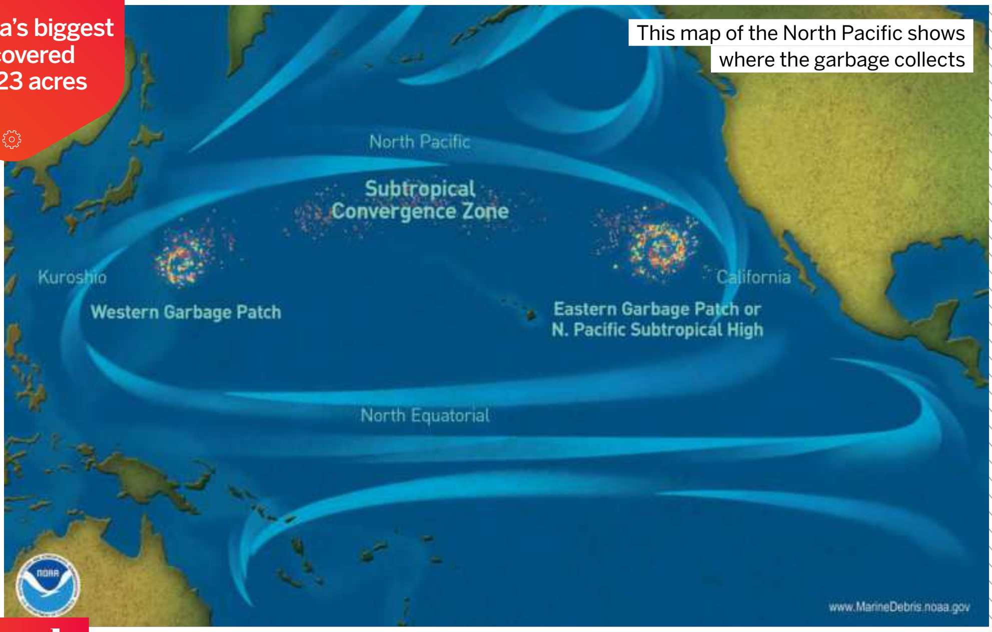
Pacific pollution

There aren't many human-made disasters that are as large or as visible as the Great Pacific Garbage Patch. There's nothing particularly complicated about what's happened here: a huge amount of rubbish has made its way into our oceans over the past decades because of negligent humans. The patch stretches from the Californian coast, all the way across the Pacific Ocean to Japan, and it's actually composed of two different tracts of trash – one on the western side of the ocean and another on the east. Currents combine to suck rubbish into a vortex, and these tiny objects can't escape. The Great Pacific Garbage Patch isn't just made up of crisp packets and drink bottles. Most of the plastic in the patch has broken down into tiny pieces that simply make the water look cloudy, and ecologists estimate that 70 per cent of ocean debris sinks to the bottom of the sea, so there could be far more below the surface.

The patch's size varies: estimates range that it sits between 270,271 and 5,791,532 square miles depending on sea movement. Some of the items in the patch are over 50 years old, because most plastics just aren't biodegradable. Scientists think it's becoming ten times bigger with every passing decade.

Unsurprisingly, the patch has a terrible effect on wildlife. Marine animals can get caught in bits of plastic or in abandoned fishing nets, and animals can die when they mistake plastic items for food. The patch has a huge impact on the ocean's ecosystems because plastics can leak pollutants and block sunlight from algae and plankton. Cleaning this up can only be effective once we've significantly reduced our huge dependance on plastics.

> **"The patch stretches from the Californian coast to Japan"**


North Pacific
Subtropical Convergence Zone
Kuroshio
Western Garbage Patch
California
Eastern Garbage Patch or N. Pacific Subtropical High
North Equatorial
NOAA
www.MarineDebris.noaa.gov

This map of the North Pacific shows where the garbage collects

Many types of plastic degrade slowly over time

DID YOU KNOW? Most of the 2018 California fires took place in summer, but the fire season lasted from February to November

Mud volcano

Most people think of lava flowing from a volcano, but in Sidoarjo, Indonesia, you'll find the world's biggest mud volcano. It was created by an explosion at a gas well drilled by an energy company, although company officials claim that an earthquake 155 miles away actually provoked the problem. There are more than 1,000 mud volcanoes around the world, but this Indonesian example is likely the only one caused by human activity.

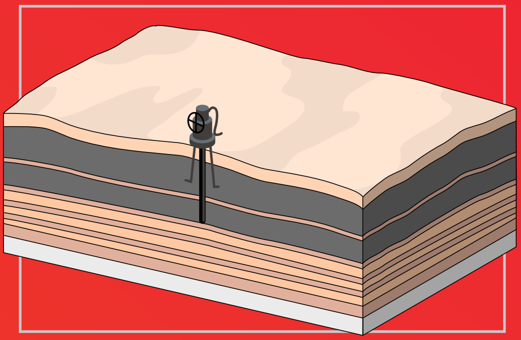
It all started on 28 May 2006, when a borehole was drilled to nearly 3,000 metres. This caused water, steam and gas to erupt from the ground nearby. The next day, water, steam and mud began to emerge again, and it's been there ever since. It's officially called Lumpur Lapindo, and is also commonly called the Lusi volcano.

Initially, the volcano erupted with 180,000 cubic metres of mud per day, but by 2011 that figure had reduced to 10,000 daily cubic metres. It might be slowing down, but the damage has already been done: 30,000 people had to be evacuated from the area, a dozen villages and more than 10,000 homes were destroyed, and metal from the mud flow has contaminated nearby rivers.

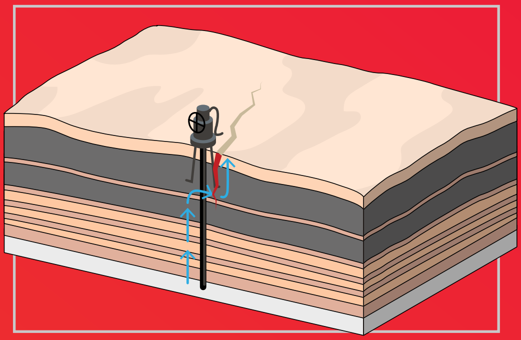
Statues from destroyed villages are still visible at the site in Sidoarjo

BIRTH OF A MUDDY ERUPTION

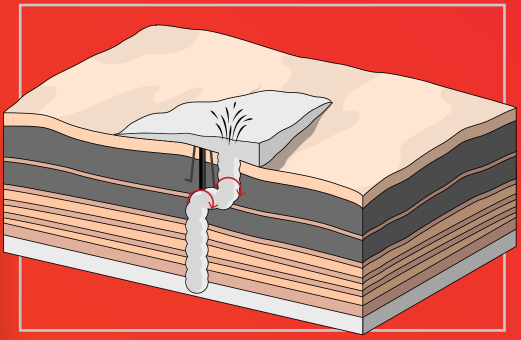
How the outflow of mud was triggered



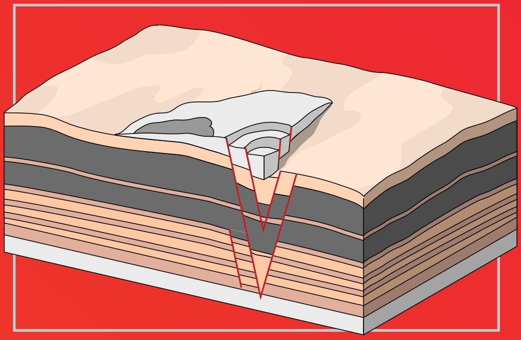
1 EXPLORATION GOES WRONG
A mining company drilled an exploration well to look for gas. The well went through a thick seam of clay, sand and eventually rock to a depth of 2,834 metres.



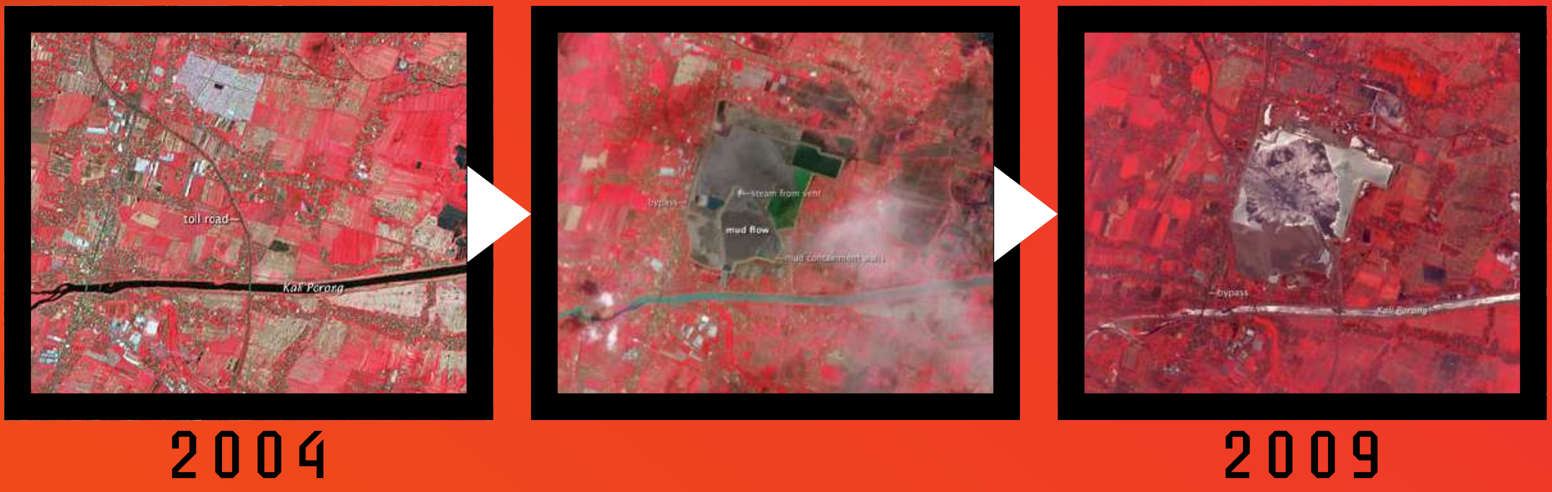
2 BUBBLING OVER
The well had no protective casing, which caused steam, water and gas to erupt from the ground nearby. Hydrogen sulphide gas and hot mud was also released.



3 A QUICK FIX
After an earthquake 155 miles away, the well lost stability. Engineers tried to fix the issue using standard methods, but they didn't work, and the well continued to behave erratically.



4 A VOLCANO IS BORN
One day later, steam, water and mud began to erupt from the well, and attempts to stop the flow were unsuccessful. Since then, the flow has continued unabated.

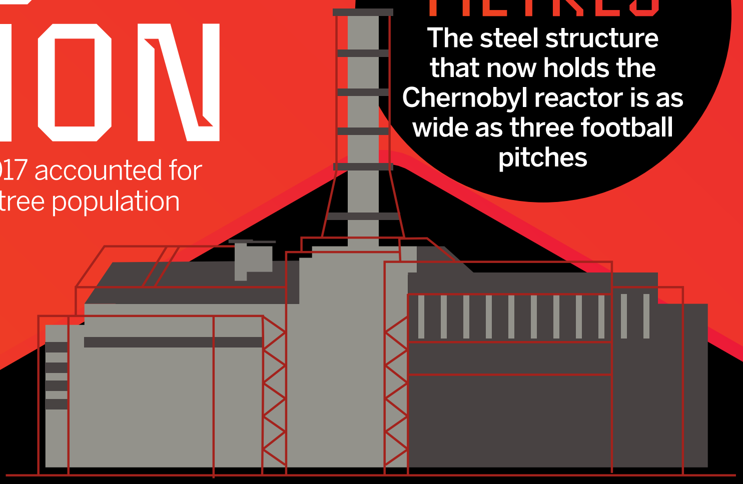


© Getty / NOAA / NASA / Illustrations by Ed Crooks

DISASTERS BY NUMBERS

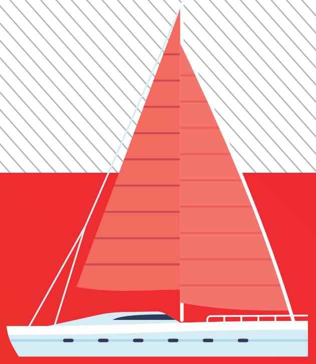
129 MILLION

Dead trees in California in 2017 accounted for about three per cent of its tree population



257 METRES

The steel structure that now holds the Chernobyl reactor is as wide as three football pitches



A yacht racer first discovered the Pacific Garbage Patch

1.8 TRILLION

There are 250 plastic pieces for every human in the world in the Pacific Garbage Patch

30,000

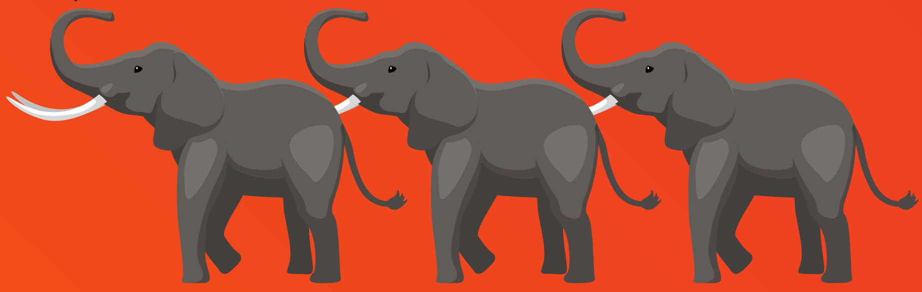
The number of people who helped clean the Deepwater Horizon spill

$148.5 BILLION

The financial cost of damage done by the 2018 California fires

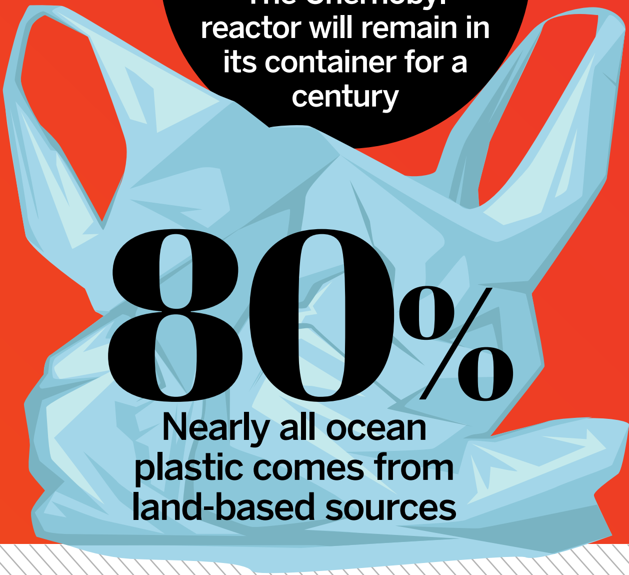
100 YEARS

The Chernobyl reactor will remain in its container for a century



28,658KG

The plastic collected by the Ocean Cleanup project in 2021 weighed more than three African elephants



80%

Nearly all ocean plastic comes from land-based sources

DID YOU KNOW? 7,000 people still live and work around Chernobyl and in the surrounding villages, despite the risks

Chernobyl remains radioactive, but it's now a popular tourist destination

16,000 MILES

The length of coastline affected by the Deepwater Horizon oil spill

£1.75 MILLION

The Aberfan Disaster Fund raised the equivalent of £32 million today

50 MILES

The chemical slick on the Songhua River would have stretched from London to Cambridge

$600 MILLION

The amount spent by the US government to decontaminate Libby

7,000

The number of ships that took part in the Deepwater Horizon response

Defective underwater cement caused the Deepwater Horizon spill

15,000

Estimated deaths caused by the 1984 Bhopal leak

THE GREAT PACIFIC GARBAGE PATCH IS SOMETIMES AS LARGE AS RUSSIA

145,000 CUBIC METRES

The amount of coal tip waste involved in the Aberfan disaster

73,962 SQUARE MILES

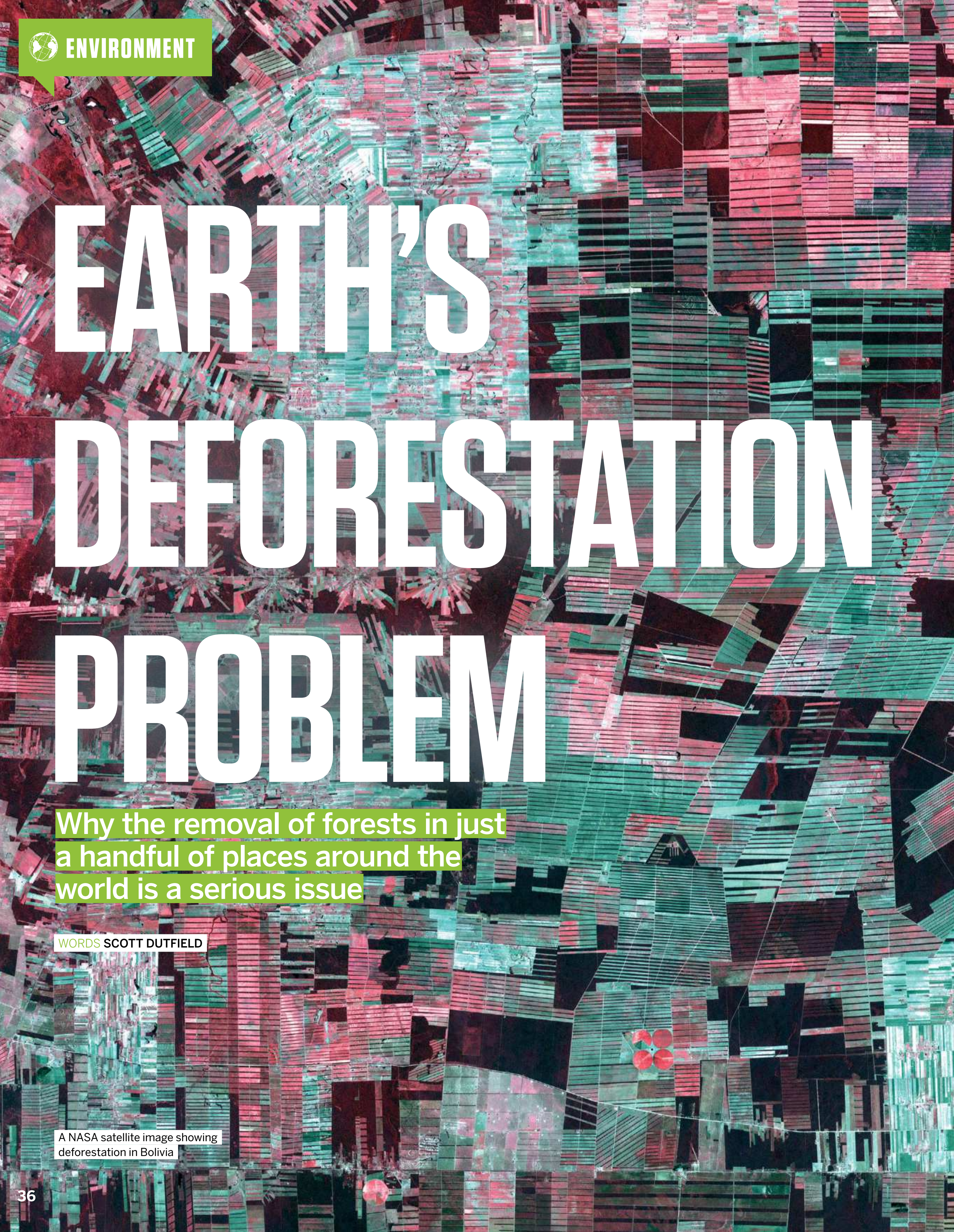
An area the size of Kyrgyzstan was contaminated by radioactive material from Chernobyl

© Getty / Alamy

EARTH'S DEFORESTATION PROBLEM

Why the removal of forests in just a handful of places around the world is a serious issue

WORDS **SCOTT DUTFIELD**



A NASA satellite image showing deforestation in Bolivia

DID YOU KNOW? There are around 3 trillion trees on Earth

In January 2021, the World Wildlife Fund (WWF) released a report on the state of the world's deforestation problem, highlighting 24 'deforestation fronts' – places where large areas of forest are under threat. The study concluded that 43 million hectares of forest around the world have been stripped away over the last 13 years. "Nature is in free fall and our climate is changing dangerously. Protecting precious forests like the Amazon is a vital part of the solution to this global crisis," said Tanya Steele, CEO of WWF UK.

Earth's forests are our planet's lungs, inhaling atmospheric carbon dioxide (CO_2) and expelling breathable oxygen. This ability to absorb CO_2 means that forests act as carbon sinks, storing CO_2 from the atmosphere and reducing the negative impact the greenhouse gas can have on global warming.

Since the 1960s, Earth's CO_2 sinks have absorbed around 25 per cent of CO_2 emissions from fossil fuels. The Amazon rainforest alone stores around 1 to 1.2 billion tonnes of CO_2 each year. However, due to growing global populations and an increase in demand for resources such as fuel, food and land, deforestation is wreaking havoc on forests around the world. 12 million hectares of tropical tree cover was lost in 2020 – and that means millions of tonnes more CO_2 heading into our atmosphere as a result. Deforestation not only reduces the number of trees available to absorb CO_2, but actively releases more carbon into the atmosphere.

During germination and growth, trees store carbon in a process called sequestration or carbon capture. When excess CO_2 is absorbed through photosynthesis, it's converted into carbohydrates and stored in the trunk or roots. Carbon typically accounts for around 50 per cent of the total volume of a tree. When a tree is cut down, a portion of its carbon content is released back into the atmosphere. Once released, it recombines with oxygen to reform CO_2. The release of CO_2 from tropical deforestation now accounts for around ten per cent of all global warming pollution.

DEFORESTATION AT ITS WORST

Here are just some of the starkest examples of deforestation

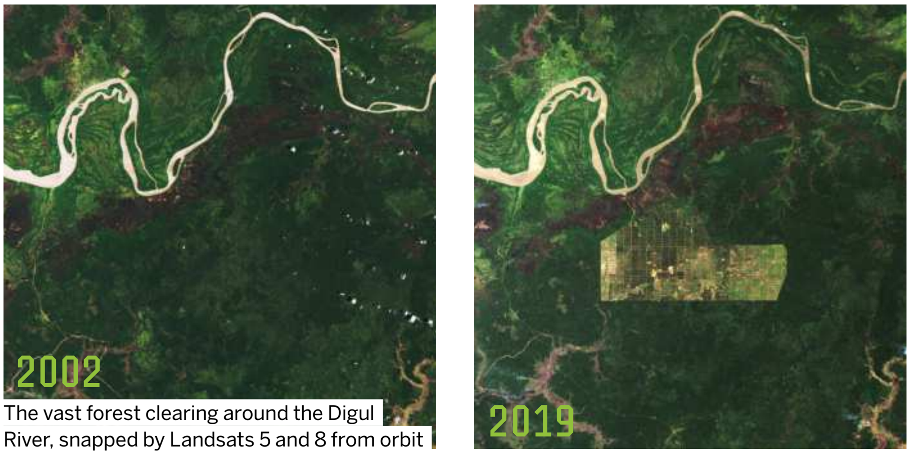
Nothing but charred remains are left behind

MADAGASCAR

For many years, forests throughout eastern Madagascar have been subjected to deforestation to make way for agricultural development. Since 2000, the nation has lost 24 per cent of its tree coverage. One of the major causes of deforestation in Madagascar is 'slash-and-burn' agriculture, also known as swidden. This method of deforestation involves cutting down extensive areas of forest and burning the fallen trees. Its purpose is to incorporate the biomass of the trees into the soil, thus increasing the soil's fertility for the benefit of agricultural crops.

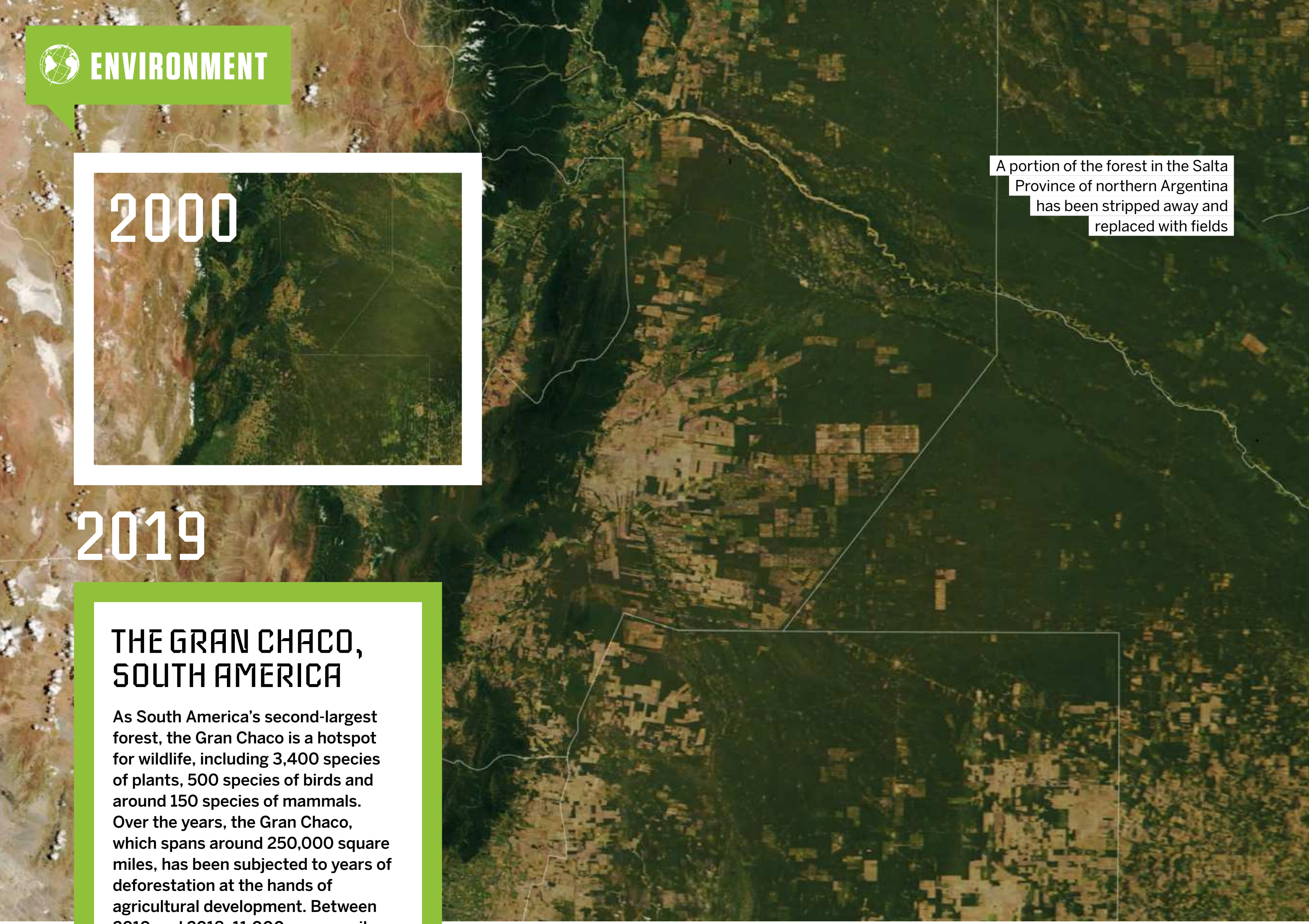
PAPUA, INDONESIA

Indonesia accounts for only one per cent of Earth's land surface, but the rainforests that cover the country's 17,500 islands are home to ten per cent of our planet's plant species. Between 2001 and 2020, Papua, also known as Western New Guinea, has lost 666,000 hectares of tree cover, equivalent to 495 megatonnes of CO_2 emissions. Agriculture is one of the biggest driving forces of deforestation in Indonesia, particularly the demand for products such as paper, plywood and palm oil. Widespread tree felling has led to Indonesia becoming the third-largest emitter of greenhouse gases following the US and China.



The vast forest clearing around the Digul River, snapped by Landsats 5 and 8 from orbit

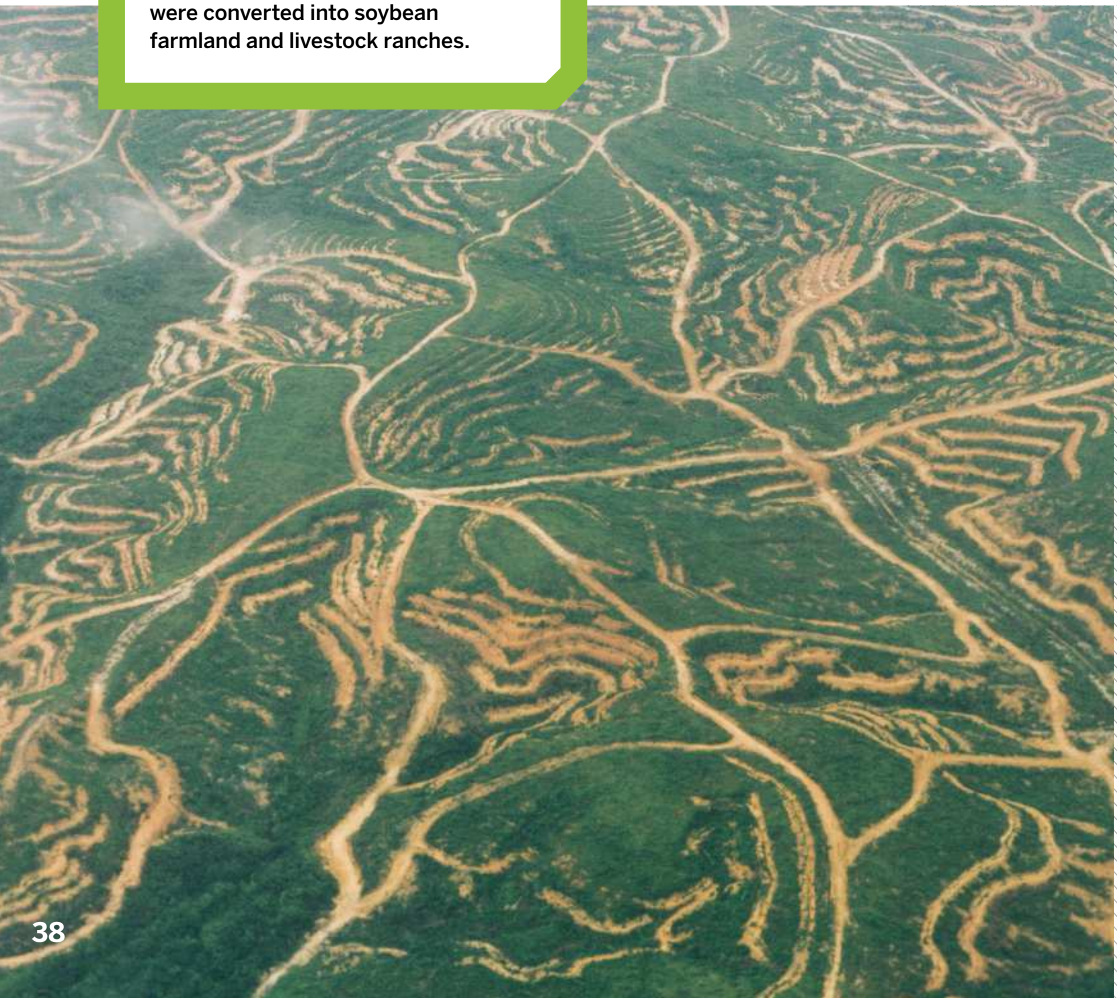
© Getty / Lauren Dauphin, using Landsat data from the U.S. Geological Survey and forest loss data from the University of Maryland



A portion of the forest in the Salta Province of northern Argentina has been stripped away and replaced with fields

THE GRAN CHACO, SOUTH AMERICA

As South America's second-largest forest, the Gran Chaco is a hotspot for wildlife, including 3,400 species of plants, 500 species of birds and around 150 species of mammals. Over the years, the Gran Chaco, which spans around 250,000 square miles, has been subjected to years of deforestation at the hands of agricultural development. Between 2010 and 2018, 11,000 square miles were converted into soybean farmland and livestock ranches.



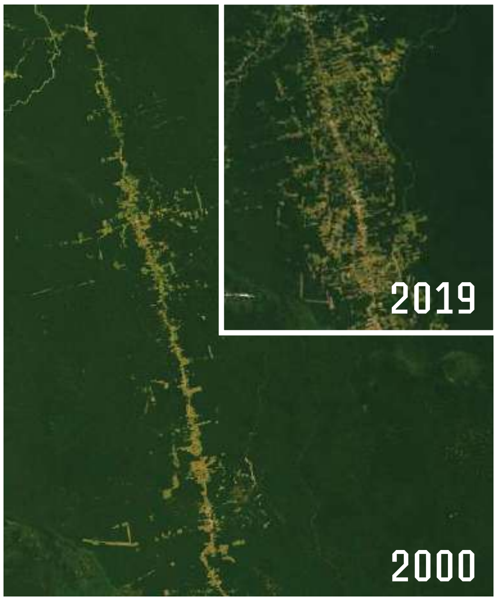
BORNEO, INDONESIA

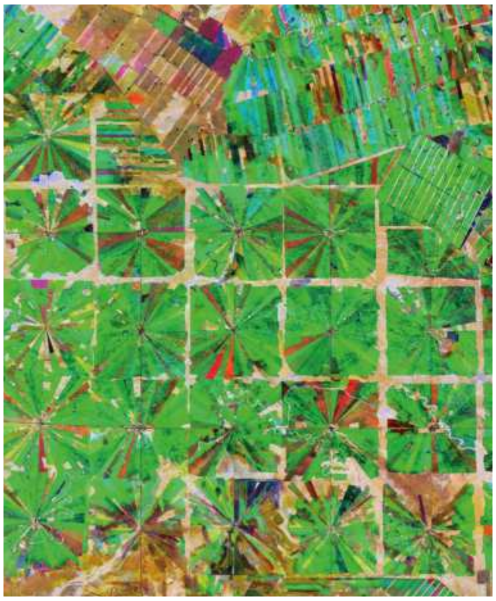
One of the biggest threats to the Heart of Borneo is palm oil plantations. As a cheap source of oil for food and fuel, palm oil is a hot commodity in Indonesia. However, it's also the cause of at least 39 per cent of forest loss in Borneo.

Malaysia and Indonesia account for more than 90 per cent of global palm oil production. As a result, countless trees have fallen to make way for palm oil plantations, and resident wildlife populations have suffered – fewer than 80,000 orangutans survive there today.

But human logging isn't the only threat to Indonesian forests. As global temperatures continue to increase, the occurrence of wildfires seems to be following suit. In 2019, wildfires blazed through 3,311 square miles of the jungle, releasing around 626 megatonnes of carbon dioxide between August and October.

DID YOU KNOW? There are 58,497 species of trees worldwide





AMAZON, BRAZIL

The Amazon rainforest is the largest rainforest on Earth and is home to ten per cent of all plant and animal species. The rainforest is part of the Amazon biome, an area that spans around 3 million square miles and crosses eight countries. Over the past 40 years, more than 18 per cent of the Amazon rainforest found in Brazil has been lost – equal to the size of California – because of logging and agriculture. These images show the amount of deforestation between 2000 and 2019 around a portion of one of Brazil's major highways, the BR-163. The highway, which is over 1,000 miles long, links soy-growing areas in the southern Amazon rainforest with ports at the river's end.

AMAZON, BOLIVIA

Since 2000, Bolivia has lost 9.5 per cent of its tree cover. This is equivalent to around 15 million acres and 2.6 gigatonnes of CO$_2$ emissions. In Santa Cruz, the largest of the nine constituent departments of Bolivia, vast areas of tropical dry forest have been cleared for agricultural use. The composite image above was created by combining three images taken by the European Space Agency's Copernicus Sentinel-2 satellite throughout 2019 and shows the Bolivian lowlands, which have been transformed into farming communities since the 1980s. Each of these radial fields is around eight square miles in size, with a small settlement, including a church, school and soccer field, at the centre of each.

Gold mining in this region is highly destructive, clearing thousands of acres of trees and poisoning the land with mercury

PERU, SOUTH AMERICA

Over the past 20 years, the Peruvian Amazon has been one of the most heavily affected areas of deforestation in the world. Around 3.12 million hectares of rainforest were lost between 2001 and 2009, with around 66 per cent of deforestation caused by illegal logging. But one region of Peru, called Madre de Dios, has seen vast losses of the forest thanks to illegal gold mining. Between 2001 and 2020, the Madre de Dios region lost around 672,000 acres of tree cover.

© Alamy / Getty / Lauren Dauphin, using MODIS data from NASA EOSDIS/LANCE and GIBS/Worldview / Copernicus Sentinel data (2019), processed by ESA

DEFORESTATION BY NUMBERS

8.1 BILLION TONNES

Deforestation causes the world's forests to release more than half of the CO$_2$ they absorb

1 TONNE

Over 100 years a single tree can absorb the weight of one-and-a-half cows

DEFORESTATION CAUSES THE RELEASE OF OVER 1.5 BILLION TONNES OF ATMOSPHERIC CO$_2$ EACH YEAR

80%

Most of the world's terrestrial species are found in rainforests

75.45 MILLION TONNES

Global annual production of palm oil

EVERY TWO SECONDS, A FOOTBALL FIELD-SIZED AREA OF RAINFOREST IS LOST

21 KILOGRAMS

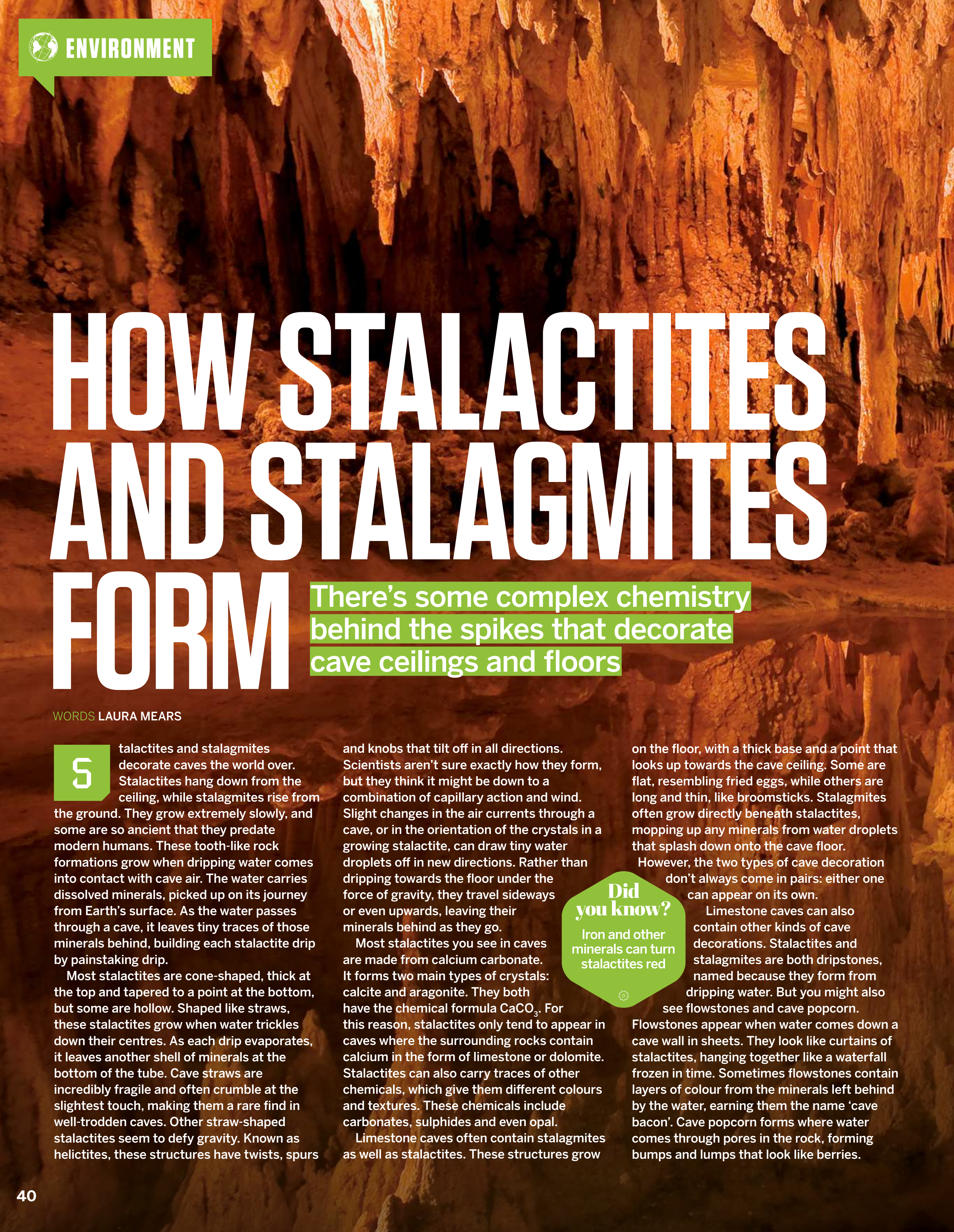
A typical tree can absorb a lot of CO$_2$ per year

40 COUNTRIES

Palm oil is one of the quickest growing monocrops found across the globe

50 MILLION HECTARES

Industrial logging concessions in the Congo Basin cover more than the area of California



HOW STALACTITES AND STALAGMITES FORM

There's some complex chemistry behind the spikes that decorate cave ceilings and floors

WORDS **LAURA MEARS**

Stalactites and stalagmites decorate caves the world over. Stalactites hang down from the ceiling, while stalagmites rise from the ground. They grow extremely slowly, and some are so ancient that they predate modern humans. These tooth-like rock formations grow when dripping water comes into contact with cave air. The water carries dissolved minerals, picked up on its journey from Earth's surface. As the water passes through a cave, it leaves tiny traces of those minerals behind, building each stalactite drip by painstaking drip.

Most stalactites are cone-shaped, thick at the top and tapered to a point at the bottom, but some are hollow. Shaped like straws, these stalactites grow when water trickles down their centres. As each drip evaporates, it leaves another shell of minerals at the bottom of the tube. Cave straws are incredibly fragile and often crumble at the slightest touch, making them a rare find in well-trodden caves. Other straw-shaped stalactites seem to defy gravity. Known as helictites, these structures have twists, spurs and knobs that tilt off in all directions. Scientists aren't sure exactly how they form, but they think it might be down to a combination of capillary action and wind. Slight changes in the air currents through a cave, or in the orientation of the crystals in a growing stalactite, can draw tiny water droplets off in new directions. Rather than dripping towards the floor under the force of gravity, they travel sideways or even upwards, leaving their minerals behind as they go.

Most stalactites you see in caves are made from calcium carbonate. It forms two main types of crystals: calcite and aragonite. They both have the chemical formula $CaCO_3$. For this reason, stalactites only tend to appear in caves where the surrounding rocks contain calcium in the form of limestone or dolomite. Stalactites can also carry traces of other chemicals, which give them different colours and textures. These chemicals include carbonates, sulphides and even opal.

Limestone caves often contain stalagmites as well as stalactites. These structures grow on the floor, with a thick base and a point that looks up towards the cave ceiling. Some are flat, resembling fried eggs, while others are long and thin, like broomsticks. Stalagmites often grow directly beneath stalactites, mopping up any minerals from water droplets that splash down onto the cave floor.

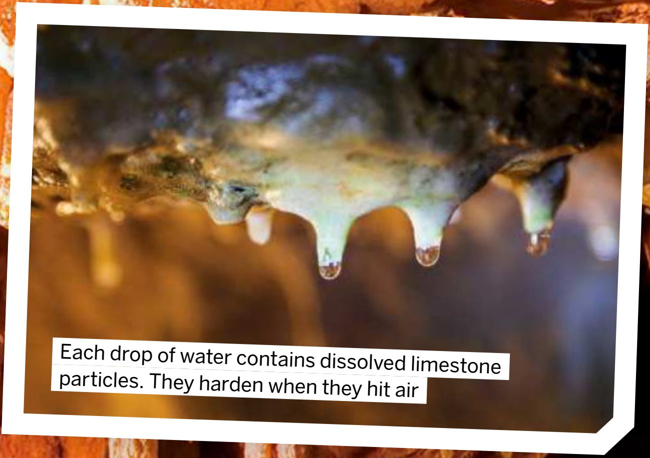
However, the two types of cave decoration don't always come in pairs: either one can appear on its own.

Did you know?

Iron and other minerals can turn stalactites red

Limestone caves can also contain other kinds of cave decorations. Stalactites and stalagmites are both dripstones, named because they form from dripping water. But you might also see flowstones and cave popcorn. Flowstones appear when water comes down a cave wall in sheets. They look like curtains of stalactites, hanging together like a waterfall frozen in time. Sometimes flowstones contain layers of colour from the minerals left behind by the water, earning them the name 'cave bacon'. Cave popcorn forms where water comes through pores in the rock, forming bumps and lumps that look like berries.

DID YOU KNOW? Stalagmites and stalactites are both types of speleothem, a word that means 'cave deposit'



Each drop of water contains dissolved limestone particles. They harden when they hit air

THE CHEMISTRY OF LIMESTONE STALACTITES

Stalactites and stalagmites form when rainwater drips through limestone rock. Along the way, it picks up carbon dioxide from the air and from any organic matter it passes as it dribbles down. The carbon dioxide reacts with the water to make a weak acid called carbonic acid. This acid can dissolve limestone, reacting with the mineral calcite and drawing it into the water as calcium bicarbonate. As water drips into a cave, it comes into contact with air again. It then lets go of the carbon dioxide and the calcium comes out of the solution, forming rock-hard calcite again.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Carbon dioxide **Water** **Carbonic acid**

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$

Calcite **Carbonic acid** **Calcium bicarbonate**

© Getty

STRANGE STRUCTURES

Stalagmites and stalactites aren't always found in caves. You can see them under concrete buildings, in lava tubes and even hanging off the side of your garage in the winter. This is because stalagmites and stalactites aren't always made from limestone. Icicles are probably the most common type of stalactite. They form when it's cold enough for water to freeze, but sunny enough for it to melt again. The melted water trickles towards the ground and refreezes before it hits the floor.

Scientists from the University of Cambridge and the University of Arizona used a combination of photographs, maths and physics to work out why icicles are pointy. They noticed that as the water trickles down, it blends together to form a sheet. That sheet gives off heat, making a warm pocket of air around the icicle. The warm air rises, which means that water freezes faster at the bottom of the icicle, making them grow long and thin at the tip.

Another kind of stalactite you might see in your everyday life is a concrete stalactite. You can find them in car parks and even on the pipes in your home. Concrete contains calcium oxide, which dissolves when alkaline liquid passes through it. When that liquid hits the air, the calcium comes out of the solution, forming a hard substance called calthemite. If the drips come fast enough, calthemite stalagmites can start to form.

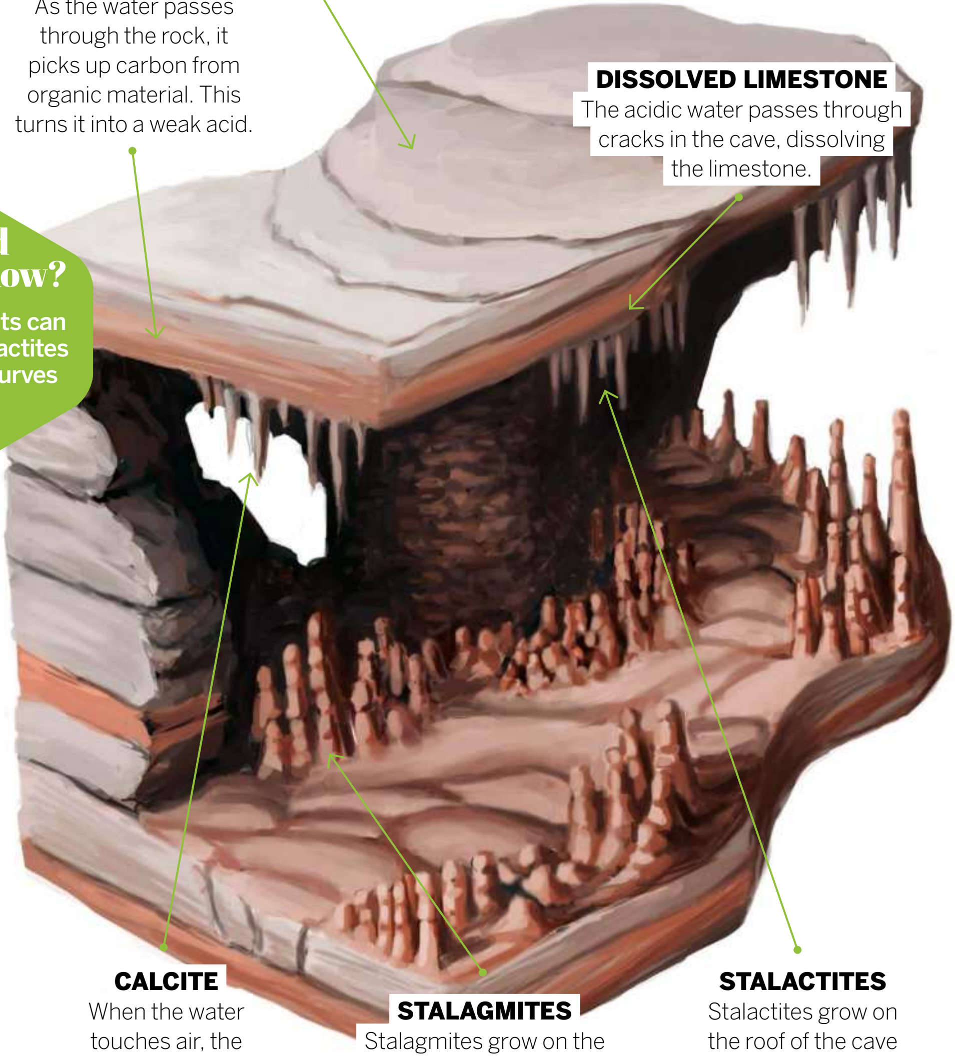
Other strange stalactites are a bit harder to find. Lava stalactites form inside tunnels called lava tubes, which carry molten rock beneath the Earth. When the roof of a lava tube starts to cool, it gets a skin, a bit like custard. Underneath, hot gases keep expanding, pushing on the skin and stretching it out to form hollow tubes that harden into solid rock.

Did you know?

Air currents can make stalactites grow in curves

INSIDE A CAVE

Stalagmites and stalactites grow inside limestone caves with a slow flow of trickling water



TRICKLING WATER
Rainwater drips through the rock above the roof of the cave.

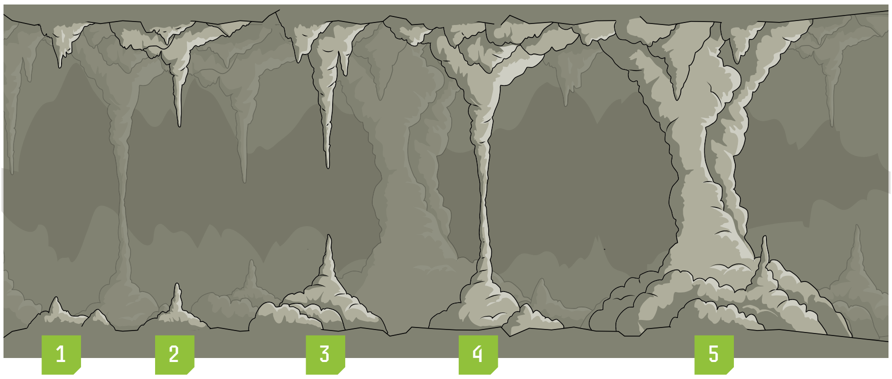
ORGANIC MATERIAL
As the water passes through the rock, it picks up carbon from organic material. This turns it into a weak acid.

DISSOLVED LIMESTONE
The acidic water passes through cracks in the cave, dissolving the limestone.

CALCITE
When the water touches air, the dissolved limestone hardens into rock.

STALAGMITES
Stalagmites grow on the floor of the cave as water drips down from the ceiling.

STALACTITES
Stalactites grow on the roof of the cave as water trickles down from above.



HOW THEY GROW

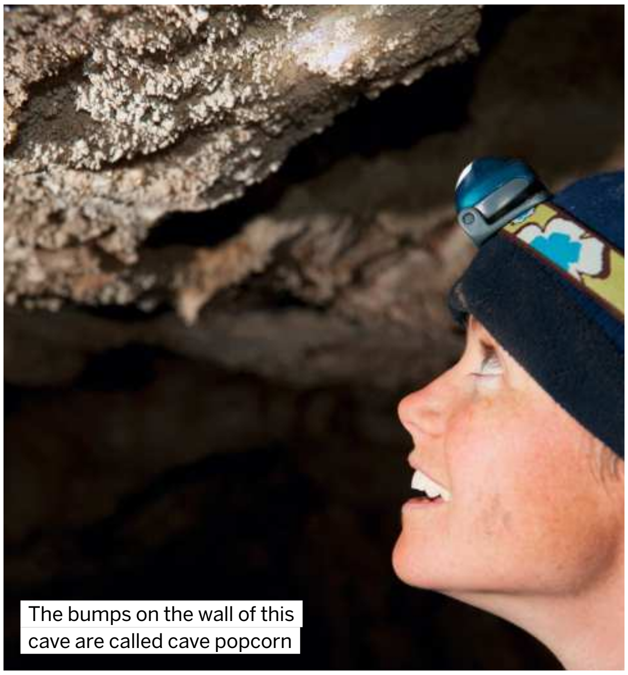
1 5,000 YEARS OLD
Stalactites grow at a rate of around 0.13 millimetres each year.

2 6,000 YEARS OLD
It takes nearly 1,000 years for a stalactite to grow ten centimetres.

3 7,000 YEARS OLD
If water drips through the cave faster, stalactites can grow three millimetres per year.

4 10,000 YEARS OLD
If they grow long enough, stalactites and stalagmites can meet in the middle.

5 15,000 YEARS OLD
These floor-to-ceiling structures are known as cave columns.



The bumps on the wall of this cave are called cave popcorn

DID YOU KNOW? Stalactites and stalagmites have rings, like trees, which reveal how old they are and how they grew

4
BREATHTAKING CAVE SYSTEMS

JENOLAN CAVES AUSTRALIA

These limestone caves in the Blue Mountains of Australia are some of the oldest in the world. Many of the stalactites and stalagmites inside are pure white calcite.

COX'S CAVE SOMERSET, UK

This cave in Cheddar Gorge is famous for its rainbow stalagmites. They get their orange, green and black colours from minerals dissolved in rainwater.

CARLSBAD CAVERNS NEW MEXICO

These caverns were carved by sulphuric acid, made when hydrogen sulphide dissolves in water. The acid cut through the limestone, leaving the caves behind.

NOHOCH NAH CHICH MEXICO

The name of this cave system means 'giant birdcage'. Now flooded, the stalactites and stalagmites form part of the longest underwater cave system in the world.

© Alamy / Getty / Illustration by Ed Crooks

HOW TO EAT POISONOUS PLANTS

Here's how toxic compounds are removed from some of our foods

WORDS **SCOTT DUTFIELD**

There are plenty of species of plants around the world that contain substances that could either kill you or cause you harm. However, there are also some species where humankind has figured out ways to bypass these poisons, or remove them, making the plants safe to eat.

For thousands of years, Aboriginal groups in northern Australia have been eating plant seeds that are so toxic that, when ingested, just two are strong enough to kill a canine. These potent plants are called cycads and can be found in tropical and subtropical regions around the world. The seeds of these plants are filled with a toxin called cycasin, which can wreak havoc on the human body. Once inside the body's digestive system, intestinal bacteria alter the cycasin, releasing a toxic metabolite called methylazoxymethanol. This metabolite enters the hepatic portal vein, the vein that supplies blood from the spleen and intestines to the liver, and starts damaging liver cells. The damage can lead to hepatic necrosis (death of liver cells), gastrointestinal irritation, liver failure and death.

Over time, Aboriginal peoples developed several ways to avoid the poisonous power of these seeds to access their high nutritional value. One of the most successful methods was prolonged leaching, whereby the seeds were harvested, dried and pounded before being left to soak in either streams or human-made waterholes for between three and seven days.

This preparation broke down the cell membranes of the seeds and allowed the toxin to leach out of them. Aboriginals also found that

POISON PANTRY

The raw foods you didn't know were filled with toxins

KIDNEY BEANS

Dried beans, such as kidney beans and soya beans, are toxic. Uncooked kidney beans contain something called phytohaemagglutinin (PHA), a type of protein called a lectin. Lectins play many different roles in the body, but some, such as PHA, can be toxic at high levels. Symptoms of PHA poisoning include violent diarrhoea and vomiting, which ease after around three to four hours. Simply soaking the raw beans for at least five hours and boiling them for at least 30 minutes destroys the toxin.

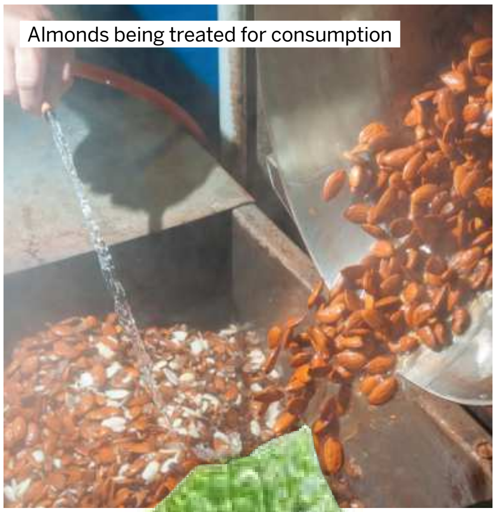
CHERRIES

Sitting in the centres of many fruits are toxins. Stoned fruits, also known as drupes, such as cherries and peaches contain a central seed or pit surrounded by fleshy fruit. Within the seed is amygdalin. Similar to almonds, when ingested it's converted by the body into cyanide. Around 200 raw cherry seeds contain around 117 milligrams of cyanide – a lethal dosage of cyanide ranges from 0.5 to three milligrams per kilogram of body weight.

DID YOU KNOW? Eating unripe ackee, a native Jamaican fruit, can cause vomiting and hypoglycaemia

ageing the seeds underground for several months achieved similar results. Like cycads, there are many other seeds, nuts and beans that need to be treated before they are safe to eat. For example, almonds are a popular snack or ingredient around the world, with around 1.56 million tonnes of them consumed globally each year. However, almonds have to undergo a pasteurisation process to make them safe to eat.

In their raw state, almonds contain a chemical called amygdalin, which is broken down by the body into the toxin cyanide. Once ingested, cyanide interferes with the ability of human cells to obtain energy from oxygen, causing the cells to die. Eating between six and ten raw untreated almonds can cause serious poisoning in the average adult, and consuming around 50 or more can cause death. To avoid harming us, almonds undergo a process of pasteurisation, similar to the treatment of milk. Batches of almonds are either heated via steam, roasted, boiled or even chemically treated to break down the amygdalin before the 'raw' seeds hit the supermarket shelves.


Almonds being treated for consumption

Cycad seeds are highly toxic, yet they have been safely eaten for thousands of years

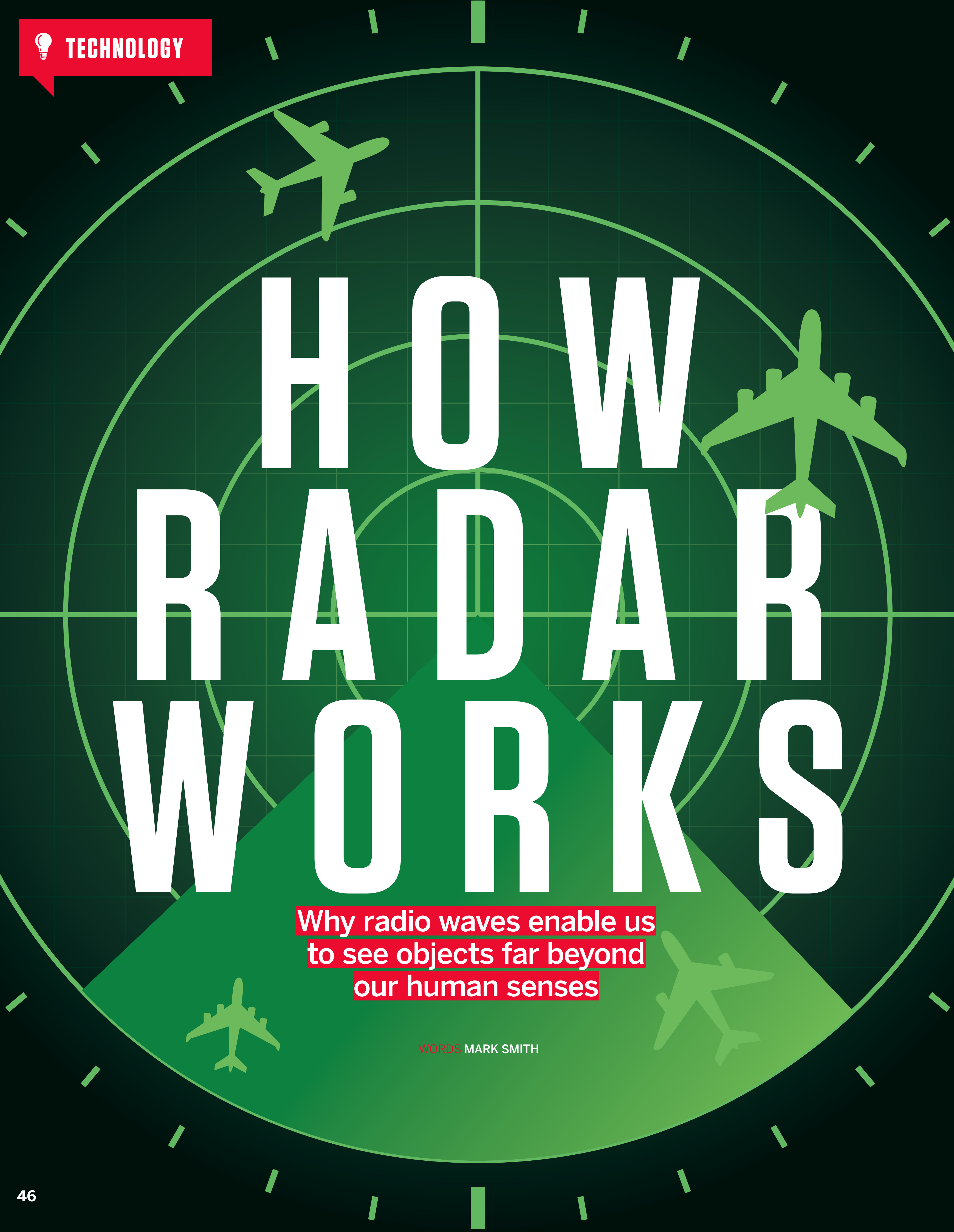
RHUBARB
Similarly to potatoes, rhubarb also has toxic leaves. Although the stems are delicious, their leaves are packed with oxalic acid – around 0.5 grams per 100 grams of leaves. Some signs of oxalic acid poisoning include vomiting, abdominal pain, convulsion and even red-coloured urine. The acid is fatal when between 15 and 30 grams is ingested, which would be between three and six kilograms of rhubarb leaves.

POTATOES
Don't worry, you've not been eating poisonous potatoes this whole time. Not unless you've been eating the leaves, stem or sprouts of the plant that is. The green parts of the potato plant are packed with toxins called solanine and chaconine. This toxic duo can cause intestinal issues such as diarrhoea, vomiting and abdominal pain when ingested. The white, edible portion of the plant has very low concentrations of the toxins, and cooking potatoes eliminates the solanine and chaconine.

BLACK LIQUORICE
This common sweet treat contains a compound called glycyrrhizin. Although harmless in moderation, when consumed in excess, liquorice root and sweets that contain liquorice root can be deadly. Glycyrrhizin lowers levels of potassium in the body, which can lead to high blood pressure and abnormal heart rhythms. Although cases of fatality are extremely rare, eating around 57 grams of black liquorice a day for two weeks can cause heart problems.

Did you know?
A cycad seed is around five per cent proteins

© Getty

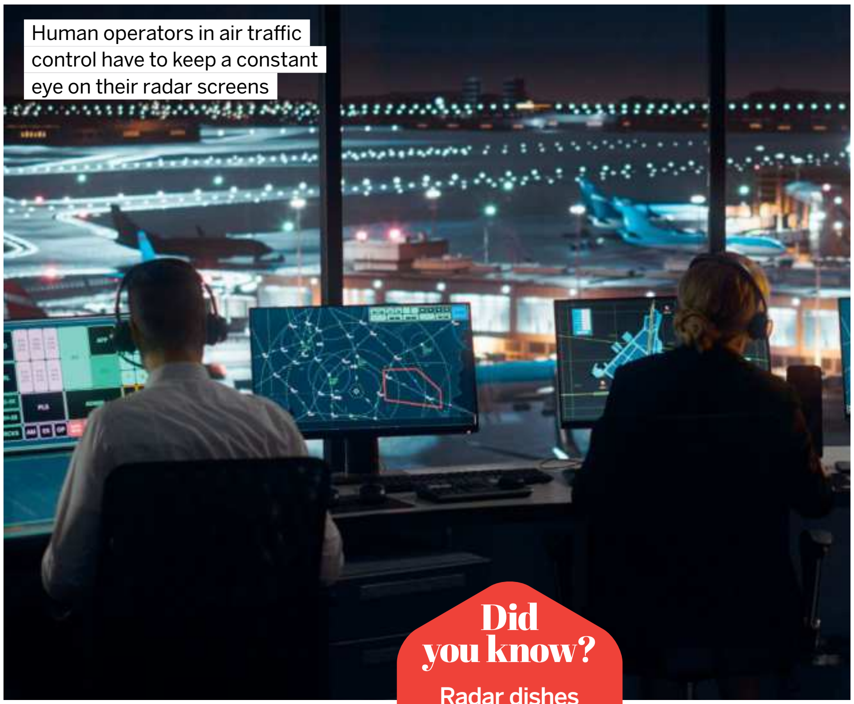


HOW RADAR WORKS

Why radio waves enable us to see objects far beyond our human senses

WORDS MARK SMITH

DID YOU KNOW? Watson-Watt was once caught speeding by a radar gun, joking afterward that he wished he'd never invented it


Human operators in air traffic control have to keep a constant eye on their radar screens

Modern military radar systems are some of the most sophisticated in the world

Did you know?

Radar dishes spin so that they can scan a wider area

Anxiously standing around a giant map in the control room, Royal Air Force (RAF) personnel would spend each day watching and waiting, until eventually the call would come: "Raid incoming. Scramble all squadrons." History is filled with turning points, and World War II was no different, with many chance events, missed opportunities and strategic blunders contributing to Hitler's plans for world domination being dashed. But among all the technical breakthroughs that helped Britain and the Allies emerge victorious, it's impossible to overstate just how important radar was in the Battle of Britain, the air war fought over UK skies in 1940. Hitler had planned to invade, but needed to gain air superiority. He sent wave after wave of his numerically superior Luftwaffe against the UK, with bombers targeting London and RAF air fields. Outgunned and outnumbered, the RAF would need a miracle to win. And that miracle was called radar.

Radar – which stands for radio detection and ranging – harnessed radio waves to detect incoming German aircraft. From radar towers dotted around the south and east of the country, the system would emit radio waves that would keep travelling until they bounced off something, like an incoming plane, and would return to be picked up by the radar receiver. By calculating how long it had taken the waves to return, skilled operators could figure out the altitude, range and bearing of incoming enemy planes. This gave the RAF enough time to scramble its own planes to meet the incoming threat, helping Britain win the battle and landing a killer blow to the invasion plans of the Third Reich.

Although this enormously successful trial by fire made radar a household name, the technology behind it started life much earlier and centred around the study of electromagnetic (EM) waves. EM radiation is a form of energy that's everywhere and can take on lots of different forms, such as radio waves, microwaves, X-rays, ultraviolet – which we receive as sunlight – and gamma rays. EM waves also form the basis of how mobile phones and wireless computer networks function.

In 1885, Scottish physicist James Clerk Maxwell came up with the idea that perhaps radio waves could be reflected by metal objects, just like light waves could. A few years later, German physicist Heinrich Hertz set out to prove it. In an experiment he conducted in 1888, he discovered that they were indeed reflected back, and in 1904 a patent was issued to a German engineer called Christian Hülsmeyer for what was termed 'an obstacle detector and ship navigation device'. It didn't have a very catchy name, but a type of early radar system had been created. Despite that, it wasn't until the 1930s that there was a need for the technology, mainly due to the invention of long-range military bombers that prompted countries to invest in a system that could detect their approach and provide early warning.

> **"It's impossible to overstate just how important radar was in the Battle of Britain"**

DOPPLER RADAR

The biggest advance in post-war radar technology was Doppler radar. With the need to defend against bombers gone, the new motivation to refine the technology was using it to track the weather. While ordinary radar can figure out range and location, Doppler can also tell us information about an object's speed. It works on the principle of the Doppler effect, the idea that waves produced by an object will be squeezed closer together if it's moving towards you, or spread out if moving away. This is invaluable for tracking weather systems. They can gather a huge amount of information, so modern Doppler radar depends on increasing processing power. Doppler radar is also what you would find in a police speed gun.

Police speed guns use Doppler radar to track how fast vehicles are moving

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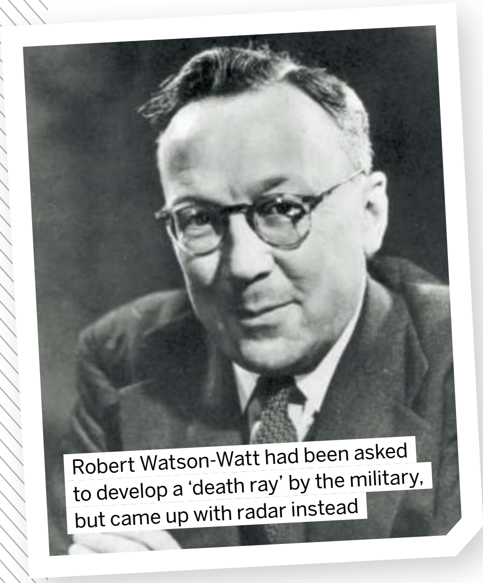
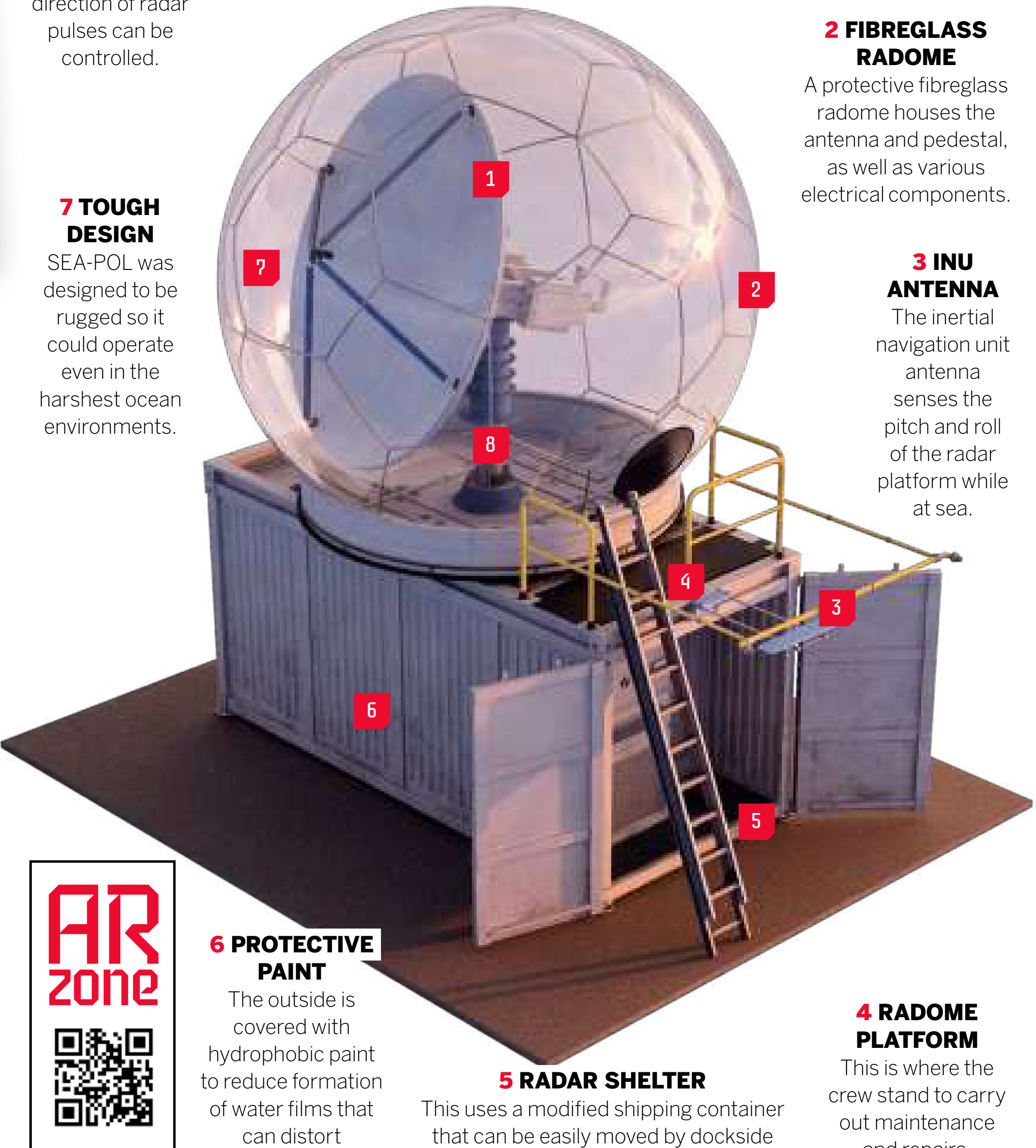


Robert Watson-Watt had been asked to develop a 'death ray' by the military, but came up with radar instead

SEA-GOING POLARIMETRIC

How the world's most advanced shipborne radar works



1 4.3-METRE ANTENNA
The reflector antenna dish is sufficiently large enough to receive powerful radar pulse reflections.

2 FIBREGLASS RADOME
A protective fibreglass radome houses the antenna and pedestal, as well as various electrical components.

3 INU ANTENNA
The inertial navigation unit antenna senses the pitch and roll of the radar platform while at sea.

4 RADOME PLATFORM
This is where the crew stand to carry out maintenance and repairs.

5 RADAR SHELTER
This uses a modified shipping container that can be easily moved by dockside equipment like forklift trucks.

6 PROTECTIVE PAINT
The outside is covered with hydrophobic paint to reduce formation of water films that can distort readings.

7 TOUGH DESIGN
SEA-POL was designed to be rugged so it could operate even in the harshest ocean environments.

8 ANTENNA POSITIONER
This allows positioning in azimuth and elevation so the direction of radar pulses can be controlled.

CHAIN HOME

In the early days of World War II, a 'chain' of radar stations had been constructed along the south and east coast of the UK. Known as Chain Home stations, they could detect incoming aircraft at a range of 80 miles. They were gigantic, at over 100 metres high. With the invention of the cavity magnetron in 1940, much smaller but more powerful radar units harnessing microwaves could be built, which meant they could be installed on ships and planes.

In 1939 Chain Home had 18 radars, growing to 53 before the war ended

AR zone

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KEY DATES IN THE DEVELOPMENT OF RADAR

1888
Heinrich Hertz discovered that electromagnetic waves could be reflected from various objects and focused into beams.

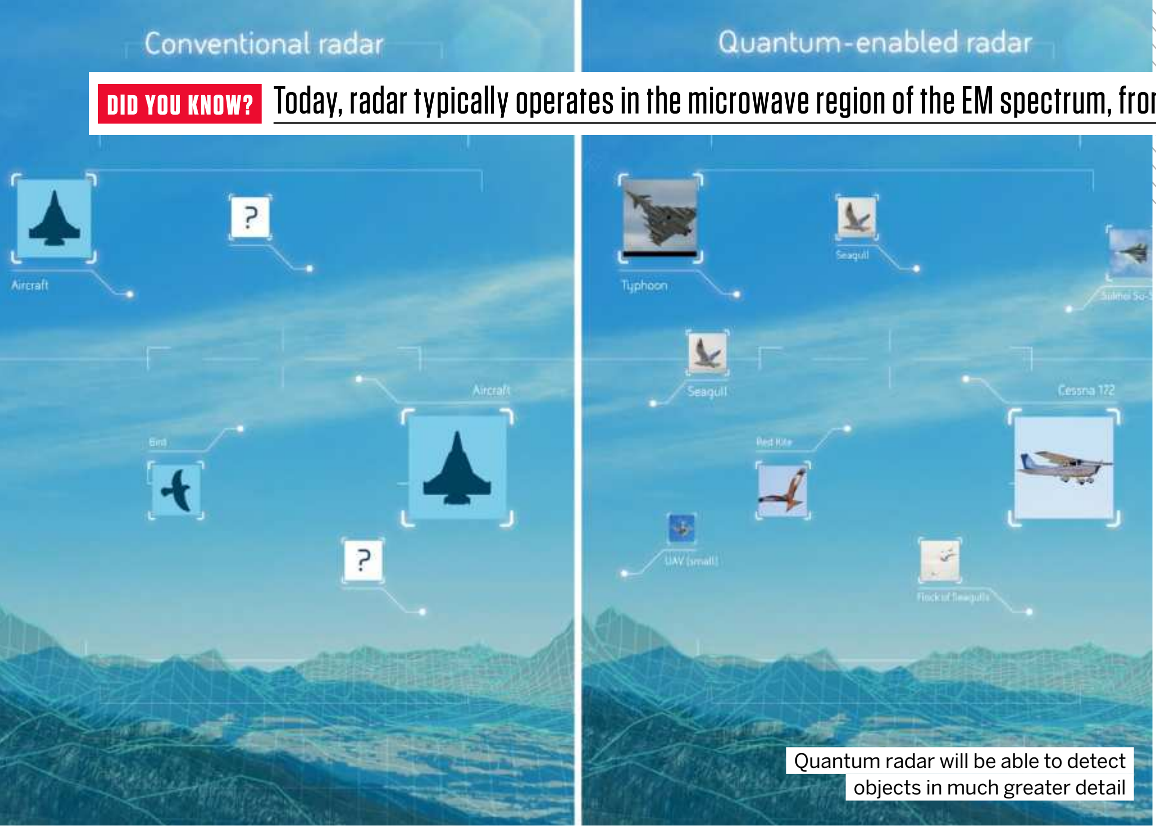
1904
German engineer Christian Hülsmeyer was granted a patent for using electromagnetic waves in an obstacle detector and navigation device for ships.

1922
Radio pioneer Guglielmo Marconi suggested short waves could be used for radio detection.

1930
A study by Lawrence Hyland from the US Naval Research Laboratory indicated it was practical to detect ships and aircraft using continuous waves.

1934
The US Army Signal Corps used continuous waves to detect targets at very short ranges, suggesting the possibility of using pulsed energy to observe targets at longer ranges.

DID YOU KNOW? Today, radar typically operates in the microwave region of the EM spectrum, from 400 megahertz to 40 gigahertz



Quantum radar will be able to detect objects in much greater detail

All of the major world powers at the time were researching radar, but it was the US and UK that were able to refine the technology. Scottish physicist Sir Robert Watson-Watt, known as 'the father of radar', built upon the science that had come before and created the workable system that formed the basis of what we have today.

Radar continues to be in widespread use today, but the technology has advanced to harness microwaves, which are at the higher frequency end of the radio spectrum and provide more accurate readings. A typical radar system has four main components: a transmitter, which generates the radio pulse; an antenna, which sends the pulse out into the ether and receives it when it's reflected back; a switch, which tells the antenna when to transmit or receive the pulses, and a receiver, which detects and turns the pulses that come back into a visual format that can be read by an operator.

The process of directing radio waves towards objects is called illumination, although radio waves are invisible to the human eye, as well as optical cameras. They are sent out at around 300,000,000 metres per second – the speed of light. Some of the reflected radio waves, or echoes, are directed back towards the radar where they are received and amplified, with the data being interpreted by skilled operators with the help of computers. Once returned, they provide information such as range and bearing.

Radio waves are cheap to generate; can pass through snow, mist and fog and are safe, unlike gamma rays and X-rays. Radar can be used to detect ships, planes and satellites. Closer to home, radar speed guns are used by the police to calculate how fast cars are going, with any that are going too fast in line for a speeding ticket. Meteorologists also use radar to map and track weather systems around the world.

Did you know?

Radar is considered an active remote sensing system

Germany lost more than 1,700 planes in the Battle of Britain, nearly twice as many as the RAF

1935
Robert Watson-Watt proposed a system almost identical to the US Army's idea and produced a successful prototype.

1937
Colonel William Blair, director of the US Army Signal Corps laboratories at Fort Monmouth, patented the first US Army radar.

1939
The invention of the cavity magnetron allowed radars to become smaller and more accurate by harnessing microwaves.

1950s
The application of the Doppler principle to radar began, leading to the creation of modern Doppler radar systems.

1990s
The continued development of computers and processing technology allowed for radar signals to be interpreted with better accuracy.

THE QUANTUM GENERATION

Henry White, sensing technologist at BAE Systems, talks about how quantum radar takes detection to a whole new level

Can you explain how this new technology works?
Every radar uses a clock to measure how long waves take to bounce off an object and come back to the antenna. The time delay tells you how far away an object is, so you can also tell how quickly it's moving while you track it. If you can make the clock more accurate, then you can begin to actually detect the shape of an object and work out exactly what it is. We're currently researching how to insert a quantum clock into radar, which is about a thousand times more accurate than the clocks we use now. These clocks aren't ready yet, but we're doing the groundwork now to use them when they are.

What can quantum radar do that traditional radar can't?
It'll be able to detect more objects, in more detail, at greater range. While now you might only be able to detect a bird, with quantum radar we think you'll be able to tell the species of bird and how many are in the flock. It should be able to tell you the make and model of a drone, which is really useful data if you're running an airport, for instance.

What do you envisage it being used for?
For the military, you should be able to identify friend or foe at much greater distances, as well as the type of physical weapons they're carrying. Being able to do this at greater range will affect how fast or stealthy you might want to design a plane. You could see civilian users, such as air traffic control, using this radar to monitor drones, which can be a real threat to them. Ultimately, it's about being able to see more clearly and give people an information advantage over potential enemies.

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INSIDE AN ENERGY-SAVING LIGHT BULB

The light bulb changed how we live, work and play. But with the race on to save the planet, new energy-efficient alternatives have come to the forefront

Modern manufacturing techniques allow for all sorts of LED designs

WORDS **MARK SMITH**

A traditional, or 'incandescent' light bulb, as they are properly known, is just a piece of glass with a really thin piece of metal that's hard to melt inside, usually tungsten. When electricity passes through it, the wire glows, producing the light that fills the room. Think of why a poker turns red when it's been in a fire and gives off light – that's pretty much what the inside of the bulb is doing.

One of the problems with them is that much of the energy they use is not actually turned into light, but heat. That's why you have to wait for them to cool down before changing them. In fact, only five per cent of the energy used is turned into light, which makes them extremely inefficient for what we actually need them to do. Also, the heat irreparably damages the filament to a point where it no longer works. Then the bulb 'blows' and has to be replaced. This has huge implications for both waste and cost.

For many years, scientists and engineers have been working on replacements for the traditional light bulb that would be kinder to the environment without compromising on effectiveness. Certain types of energy-saving light bulbs have actually been around for decades. One of the first was the halogen bulb, developed in 1955. Halogen bulbs are similar to incandescent bulbs, but contain a small amount of halogen gas, which mixes with tungsten vapour. It then deposits it back onto the filament instead of on the inside of the bulb, meaning it can shine more brightly and extend its life span.

In 1976 we saw compact fluorescent lamps (CFLs) emerge. They were the first truly energy efficient bulbs available to everyday consumers and used between 70 and 80 per cent less energy than a traditional bulb. They can last for around 8,000 hours – 50 times longer than an incandescent bulb – making them much more efficient and cost-effective. They work by having an electric current pass through a tube containing a gas called argon and a tiny amount of mercury vapour. This process generates ultraviolet light, which is invisible to humans, but which excites the molecules in a fluorescent coating – called phosphor – on the inside of the tube, which then emits visible light. They marked a big step forward in energy-saving technology and are still the most commonly used type of energy-saving bulb today.

An even more efficient type of bulb is the light-emitting diode (LED). Although they actually trace their roots back to 1927, we only really started to see them in widespread use in the last couple of decades. But they were pricey. Now they are more affordable and likely to be found in most places, from homes to office buildings. Because they turn around 95 per cent of their energy into light, they are far more efficient than traditional bulbs and last much longer. An LED differs from all the others, as solid matter produces the light, not filaments or gases. This solid-state material is a semiconductor called a diode, made of material – usually aluminium-gallium-arsenide (AlGaAs) – that allows electricity to pass through it easily. When the electricity passes through the diode, it emits electromagnetic particles called photons, which produce the light we see in our rooms and on our streets. LED bulbs can last for up to 50,000 hours, so may not have to be replaced for up to ten years, unlike traditional bulbs that often only last for months or even just weeks.

Did you know?

There are estimated to be 600 million light bulbs in the UK

ENVIRONMENTAL IMPACT

While energy-saving bulbs are more efficient and help consumers save money, their biggest benefit is to the environment. LED lights need much less energy to produce light. A typical 84-watt fluorescent bulb can be replaced by a 36-watt LED and provide the same level of light. By using less energy, less needs to be produced at source – like using fossil fuels at a power station – in order to light our homes and cities. This decreases greenhouse gas emissions. Also, unlike some previous generations of bulbs that contained materials like mercury, LED lights don't contain any toxic materials, meaning they can be easily disposed of in a way that won't harm the environment.

Energy-saving light bulbs are a key part of fighting climate change

DID YOU KNOW? The increase in the use of LED lights will reduce the world's energy costs by over $30 billion (£22.5 billion)

MAKING LIGHT

How the most common type of energy-efficient bulb produces light

1 BASE
This is where the bulb is attached to the light fitting, typically with either a screw or bayonet fitting.

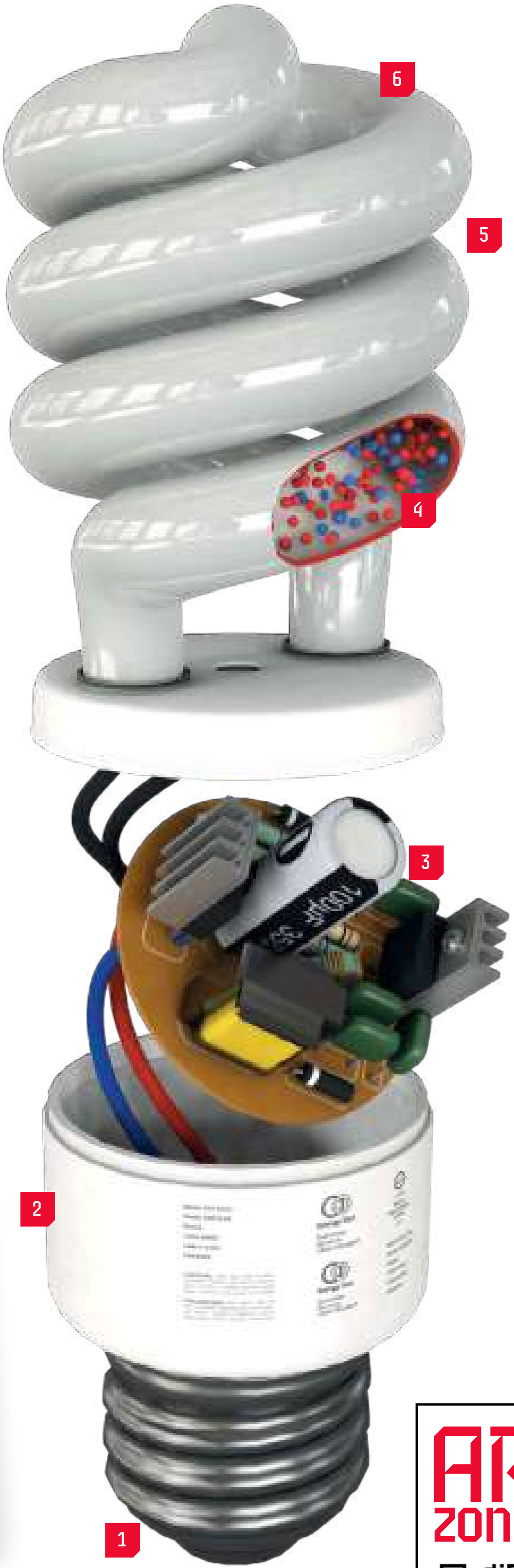
2 BALLAST HOUSING
This section contains and protects the ballast, which is what enables the light to function.

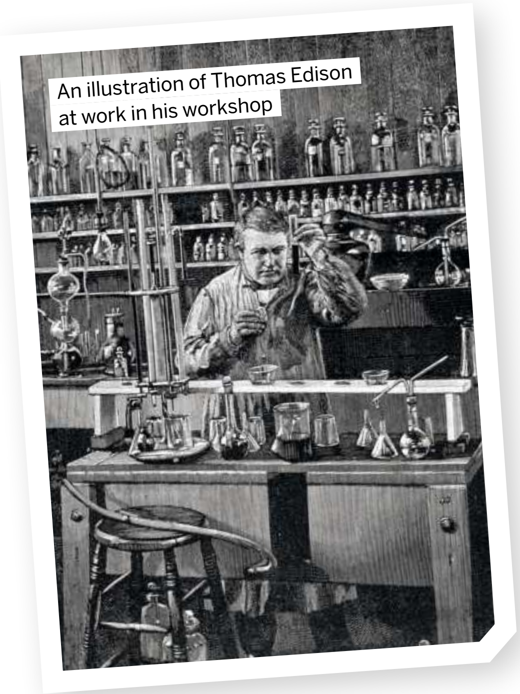
3 BALLAST
When voltage is applied to the ballast, the mercury vapour is energised.

4 ARGON AND MERCURY
Both elements are energised, which starts the process of creating light.

5 ULTRAVIOLET LIGHT
The excited gases create ultraviolet light, which collides with the tube to create visible light.

6 COVER
The cover protects the inner workings and makes it safe for handling.




An illustration of Thomas Edison at work in his workshop

> "LED bulbs can last for up to 50,000 hours, so may not have to be replaced for up to ten years"

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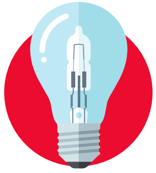
HOW DO BULBS DIFFER?

INCANDESCENT

AVERAGE LIFE (HOURS): 1,200

TYPICAL WATTAGE: 60

TYPICAL CANDELA: 50 to 55
The 'traditional' bulb has been largely phased out.

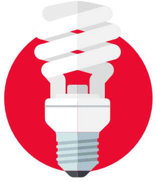


HALOGEN

AVERAGE LIFE (HOURS): 2,000

TYPICAL WATTAGE: 45

TYPICAL CANDELA: 65
The first foray into the world of energy-saving bulbs.



CFL

AVERAGE LIFE (HOURS): 8,000

TYPICAL WATTAGE: 13 to 15

TYPICAL CANDELA: 72
CFLs can last ten times longer than incandescent bulbs.

LED

AVERAGE LIFE (HOURS): 25,000

TYPICAL WATTAGE: 6 to 8

TYPICAL CANDELA: 72
The most energy-efficient light bulb on the market today.

© Getty / Illustration by Adrian Mann

Complex metal designs can be produced more cost-effectively when 3D printed

3D PRINTING WITH METAL

How 3D printers can materialise sturdy rocket parts and more in metal

WORDS **AILSA HARVEY**

Since the first 3D printers appeared in the 1980s, their applications have continued to grow. Initially, they were used mainly for speedy prototyping and their filaments were limited to printing plastics. This flexible material is the simplest option for 3D printing as it can be easily melted and shaped. At room temperature, most metals are solid and are difficult to manipulate. However, today's technology allows us to 3D print in metal.

To make small shapes in metal, 3D printing is a far quicker method compared to cutting from a sheet. The latter is a subtractive process, involving carving roughly shaped chunks of metal. This can be extremely costly and time consuming. Instead, 3D printing is an additive process that uses carefully selected dimensions to build up a 3D piece layer by layer.

Some metal printing methods have more steps than others, based on the method of printing. Selective metal sintering prints metal by combining it with plastic. This makes the printing process similar to that of printing exclusively with plastic. The difference is that when it's removed from the machine, it isn't a completed all-metal piece. Further steps strengthen the printed part and remove the unwanted plastic.

SPACE APPLICATIONS

Metal printing is favoured by many engineers tasked with making space components such as metal parts for rockets. Because rocket engines need to be able to withstand very high temperatures, an Inconel copper superalloy powder is often chosen. Inconel is a distinctive class of superalloys recognised for resistance to corrosion and oxidation.

Instead of incorporating plastic into the metal filament, printing for space-based applications is better suited to direct metal laser sintering. To produce dense rocket parts, loose metal powder is laid in layers. Between each layer being placed, a laser is pointed onto the metal powder. The laser traces the precise shape dictated by the digital file, melting and binding the metal in the process. This is repeated for each layer until the solid metal shape is submerged in the excess metal powder.

NASA is currently funding research into metal 3D printing in low gravity. Depending on the success of space-based manufacturing, the future could include printing a base on the Moon.

Combustion chambers and nozzles are rocket engine parts that can be 3D printed, yet still withstand high temperatures

MELTING METAL

From digital file to printed part, follow the steps of the metal-printing process

1 DIGITAL DESIGN

A computer-aided design (CAD) file is logged with the dimensions of the desired shape.

2 METAL FILAMENT

The filament is inserted into the printer. It's a mixture of metal powder and plastic.

3 PRINTING

Through a small nozzle, the molten plastic and metal is piped in layers, copying the CAD design.

4 GREEN PART

The object that's printed is made to be about 20 per cent bigger in each dimension than the CAD file design. This is because the plastic that binds the metal powder is yet to be removed.

5 BROWN PART

To begin to debind the wax, the green part is washed in a machine. This can take hours or days, depending on the thickest section.

6 METAL PART

The brown part is placed into a sintering oven to remove the remaining plastic and meld the metal together. The result is a fully metal printed part.

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DEEP-SEA DIVERS

These machines explore the greatest depths of our planet

WORDS **SCOTT DUTFIELD**

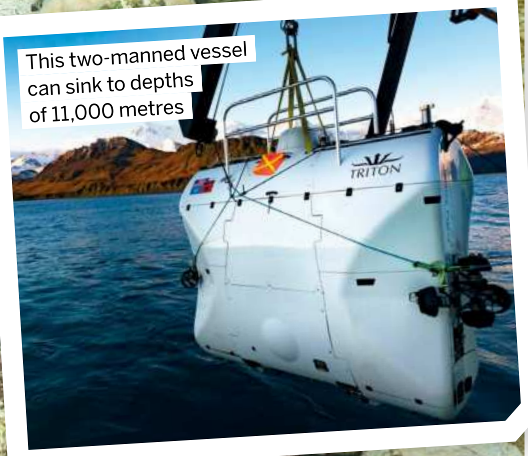
DID YOU KNOW? The deepest a human has ever dove in a submarine is 10,927 metres

More than 80 per cent of the world's oceans remain unexplored, but several submersibles are working to bring that percentage down. The deep ocean is considered to start around 200 metres below the surface, where light begins to dim, also referred to as the euphotic zone. The deep ocean is further divided into descending zones, such as the twilight zone (down to 1,000 metres), midnight zone (down to 4,000 metres) and so on until the last defined zone, the hadal zone. The hadal zone, also known as the hadopelagic, sits between 6,000 and 11,000 metres below the ocean surface. The deepest dive any vehicle has ever made was achieved by the Deepsea Challenger, a 109-centimetre-wide manned submersible that reached the deepest point in the Mariana Trench, called Challenger Deep, in 2019, travelling more than 10,000 metres below the surface.

The world's first truly submersible boat was designed by British mathematician William Bourne in 1578. The wood-framed vessel was covered in waterproof leather and used an early version of the ballast tank to move water in and out of the boat to make it submerge and resurface. Following Bourne's innovation, scientists and engineers have created a whole host of vessels and machines to explore the great unknown depths.

One of the earliest examples of a vessel that could venture into the deep ocean was created in a collaboration between the United States Navy and the Woods Hole Oceanographic Institution (WHOI). Together they created the DSV Alvin, a manned deep-ocean research submersible that made its maiden descent in 1964 to around 10.6 metres.

Alvin has since been used in geological studies and whale surveys, and in 1966 was used to search for a lost thermonuclear weapon, or H-bomb, off the coast of Spain. Alvin is still in use today, having had several upgrades over the decades, and is currently getting overhauled after exploring larval distributions of species in the Gulf of Mexico.



This two-manned vessel can sink to depths of 11,000 metres

The Alvin, a manned deep-ocean research submersible from the 1960s

One of the biggest challenges of deep-sea exploration is battling physics. Although Alvin is one of the original submersibles, it's only descended to around 4,000 metres, and one of its limitations is its ability to battle hydrostatic pressure. At sea level, there's an atmospheric pressure of around 10,000 kilogram force per square metre being applied to your body. However, at the bottom of the Mariana Trench, which is seven miles deep, that pressure increases more than 1,000 times. This is because the deeper you descend into the water, the more there is water that sits above you, pressing down on you.

To tackle this, scientists and engineers have created robots and vehicles out of robust materials that can withstand the pressures at the deepest regions of our oceans. For example, the world's toughest manned submersible, TRITON 3600/2, also known as the Limiting Factor, is equipped with a 90-millimetre-thick titanium pressure hull that can withstand the hydrostatic pressure at over 11,000 metres.

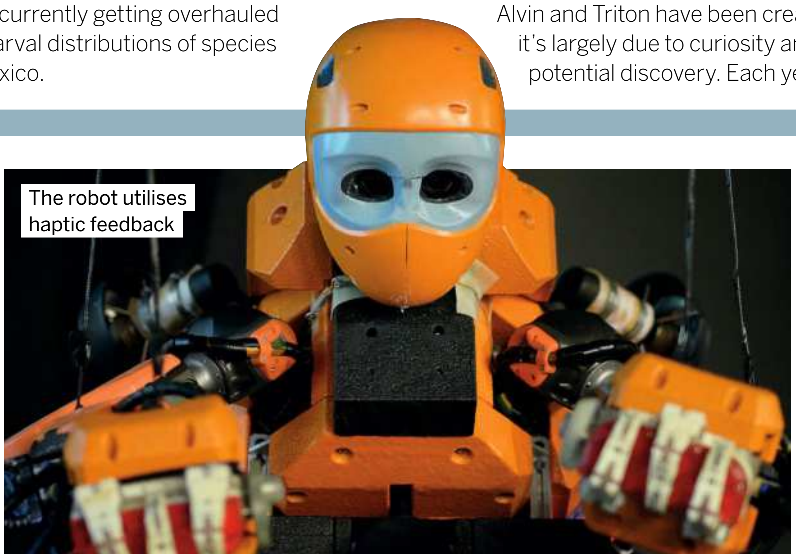
As to why deep-sea divers such as Alvin and Triton have been created, it's largely due to curiosity and potential discovery. Each year

Did you know?

The first military submarine, 'Turtle' was built in 1775

HUMANOID ASSISTANT

Meet the humanoid robot ready to search the seafloor and lend a helping hand in underwater missions. The OceanOne robot is an unmanned underwater vehicle created by Stanford University to step in (or rather, swim in) to replace or assist human divers. The robot is remotely piloted by an operator on the surface and can assist in the assembly of marine infrastructure and repairs, collect benthic samples and record research data. In 2017, OceanOne joined a team of human divers in Santorini, Greece, to investigate underwater volcanic structures, providing illumination and taking measurements of volcanic features.



The robot utilises haptic feedback

© Getty / Richard Varcoe on behalf of Caladan Oceanic LLC

deep-sea rovers and robots make many discoveries in the deep ocean, slowly adding pieces to the puzzle of what lies beneath the surface. In 2020, researchers using a remotely operated vehicle (ROV) discovered a new species of sponge in the Pacific Ocean more than 2,000 metres down. The weird-looking sponge has been named *Advhena magnifica*, which translates from Latin as 'magnificent alien', due to its extraterrestrial appearance.

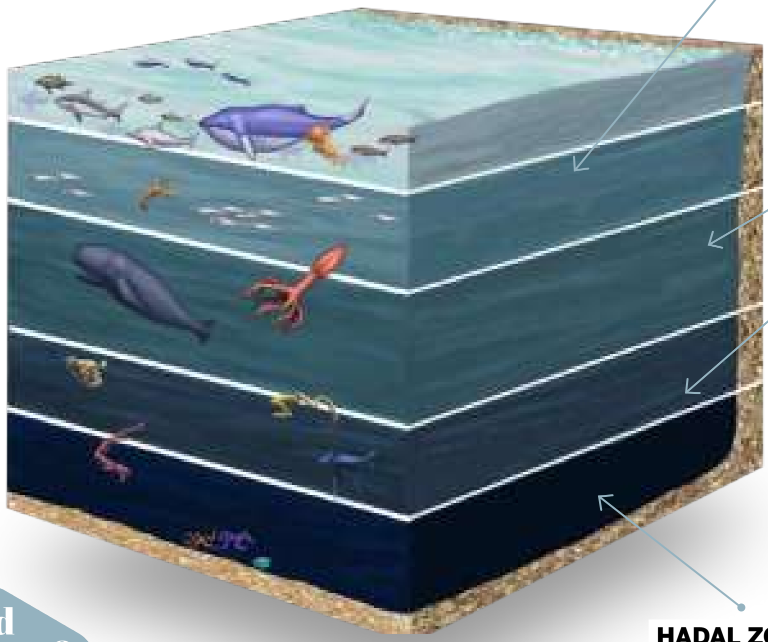
Other than sheer curiosity, there are many reasons why scientists want to uncover the truth about what lies in the depths of the ocean. Vessels can explore shipwrecks such as the Titanic, install deep-sea communication cables or search for new resources. One of the many discoveries that can come from exploring the ocean are potential new medicines. Many pharmaceuticals are found in or derived from terrestrial plant species, such as aspirin, which was originally extracted from willow trees. However, there has been a wash of medicines derived from marine invertebrates that are used to treat human diseases. For example, aquatic invertebrates called bryozoa produce a chemical called bryostatin, which is used in the treatment of leukaemia and melanoma cancers.

Deep-sea exploration can also help scientists understand more about the world above the surface. Benthic Rover II, also affectionately referred to as the Wall-E of the sea, is a car-sized robot that descends into the abyss to collect data on climate change. This autonomous mobile laboratory collects data on carbon cycling in the deep ocean. Carbon enters the deep ocean as a part of Earth's global carbon cycle, coming from plant, animal and waste matter. Creatures and microbes living on the seafloor digest some of that carbon, and the rest is stored in sediment.

To monitor changes in this carbon cycle, the Monterey Bay Aquarium Research Institute (MBARI) created Benthic Rover II, which has been collecting data for seven years off the coast of California. An unmanned wave glider on the water's surface keeps track of Benthic Rover II's position and the status of its data collection during operation.

INTO THE DEPTHS

Who can dive the furthest?



TWILIGHT ZONE
Humans: 40 metres
HMS Turbulent: 91 metres

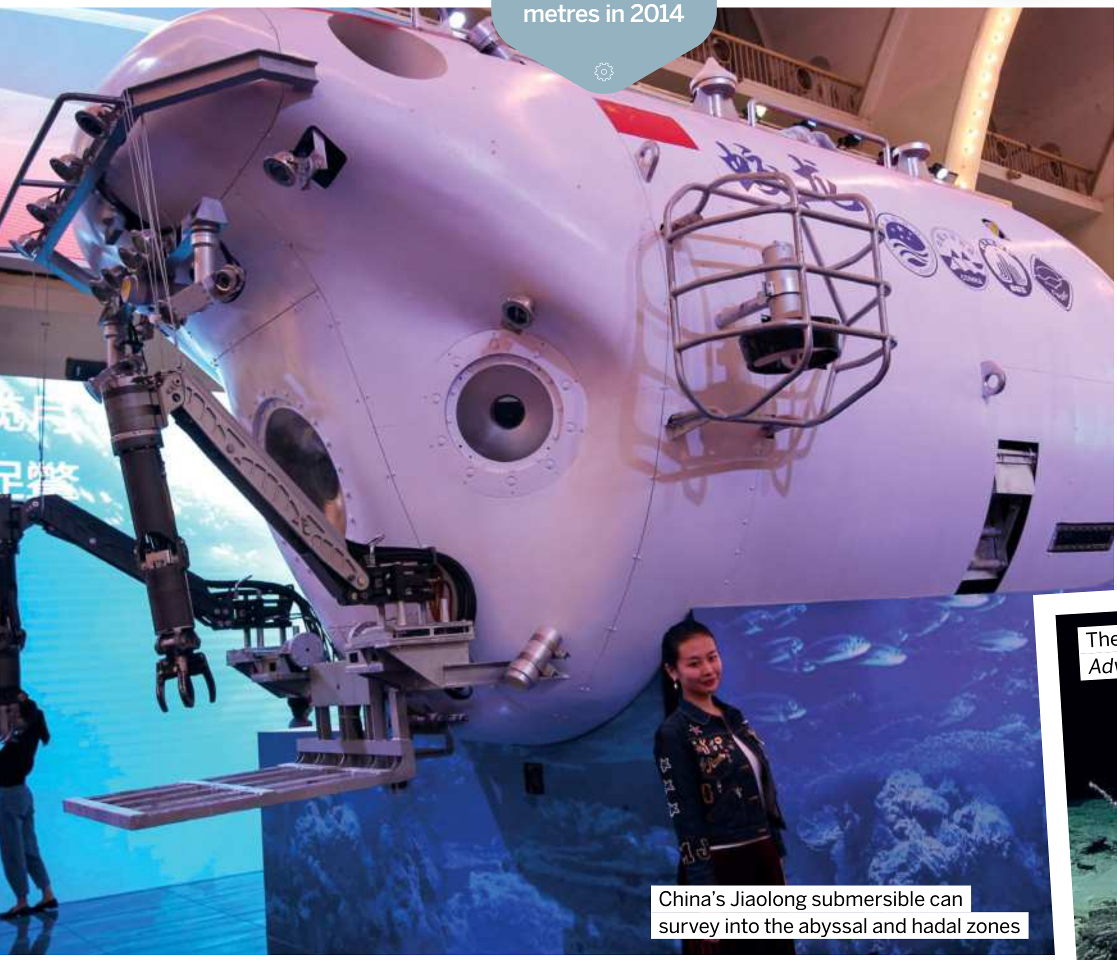
MIDNIGHT ZONE
Sperm whale: 2,000 metres
The Titanic: 3,800 metres

ABYSS ZONE
Alvin: 4,500 metres
Benthic Rover II: 4,000 metres
Tripodfish: 4,700 metres
Jason: 6,500 metres

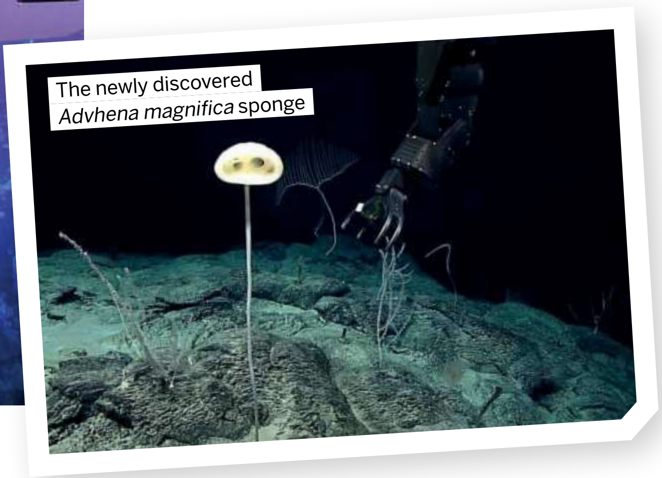
HADAL ZONE
Deepsea Challenger: 10,898 metres
Jiaolong: 7,500 metres

Did you know?

Egyptian Ahmed Gabr dove to 332 metres in 2014



China's Jiaolong submersible can survey into the abyssal and hadal zones



The newly discovered *Advhena magnifica* sponge

DID YOU KNOW? In 2020, astronaut Kathryn Sullivan became the first person to travel both to space and to the Challenger Deep

AR zone

SCAN HERE

DIVING WITH BENTHIC ROVER II

The autonomous deep-sea vehicle that's checking the health of our oceans

TECH SPECS

LENGTH:
2.6 metres

WIDTH:
1.7 metres

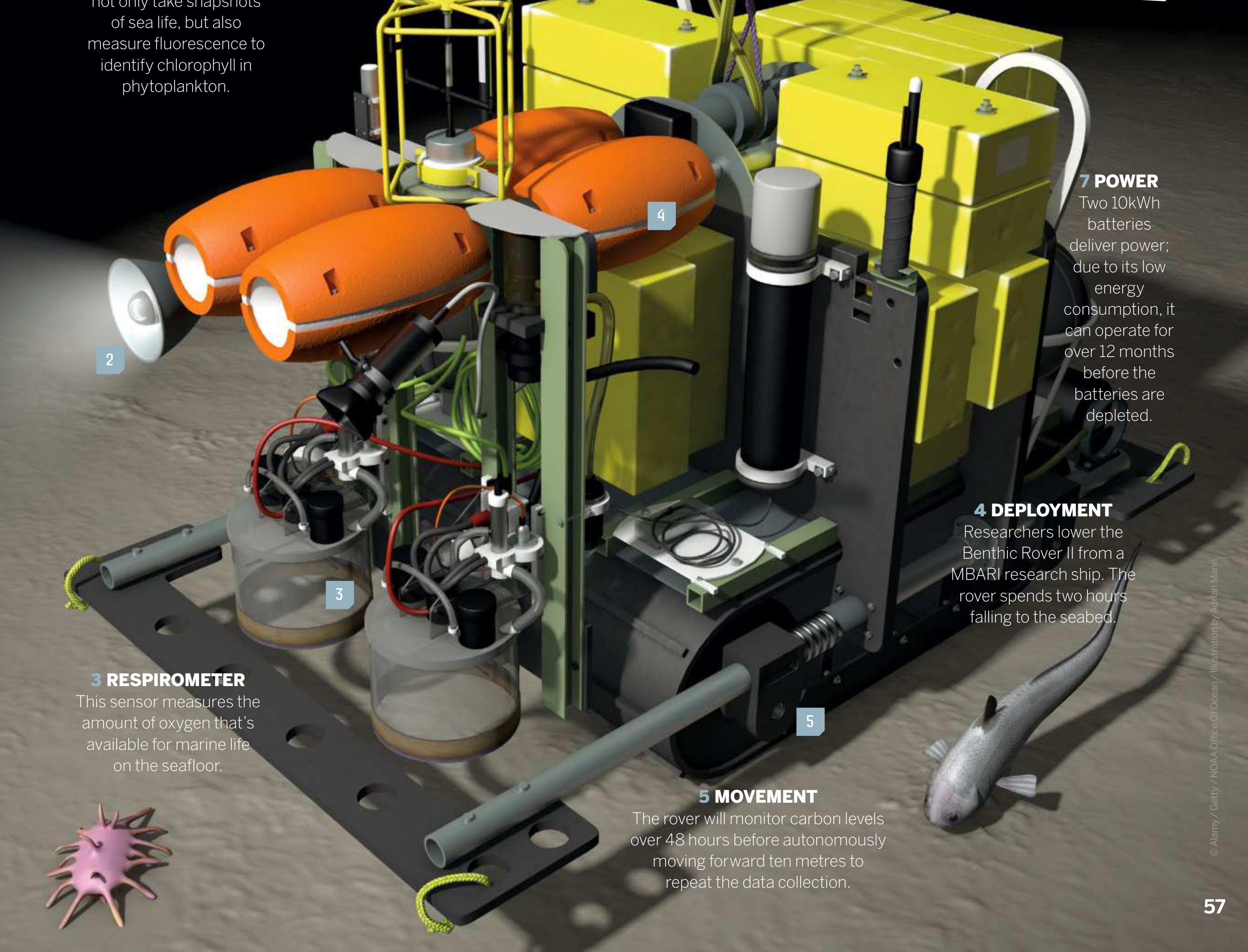
HEIGHT:
1.5 metres

CONSTRUCTION:
Made of corrosion-resistant titanium and plastic

1 CURRENT METERS
These sensors monitor currents along the seafloor. When optimal currents are detected, the rover will move up into the current to reach an undisturbed site for data collection.

6 BUOYANCY
The rover uses 18 blocks of foam, four floats and steel ballast to remain rooted to the seabed.

2 CAMERAS
At the front of the rover is a set of cameras that can not only take snapshots of sea life, but also measure fluorescence to identify chlorophyll in phytoplankton.



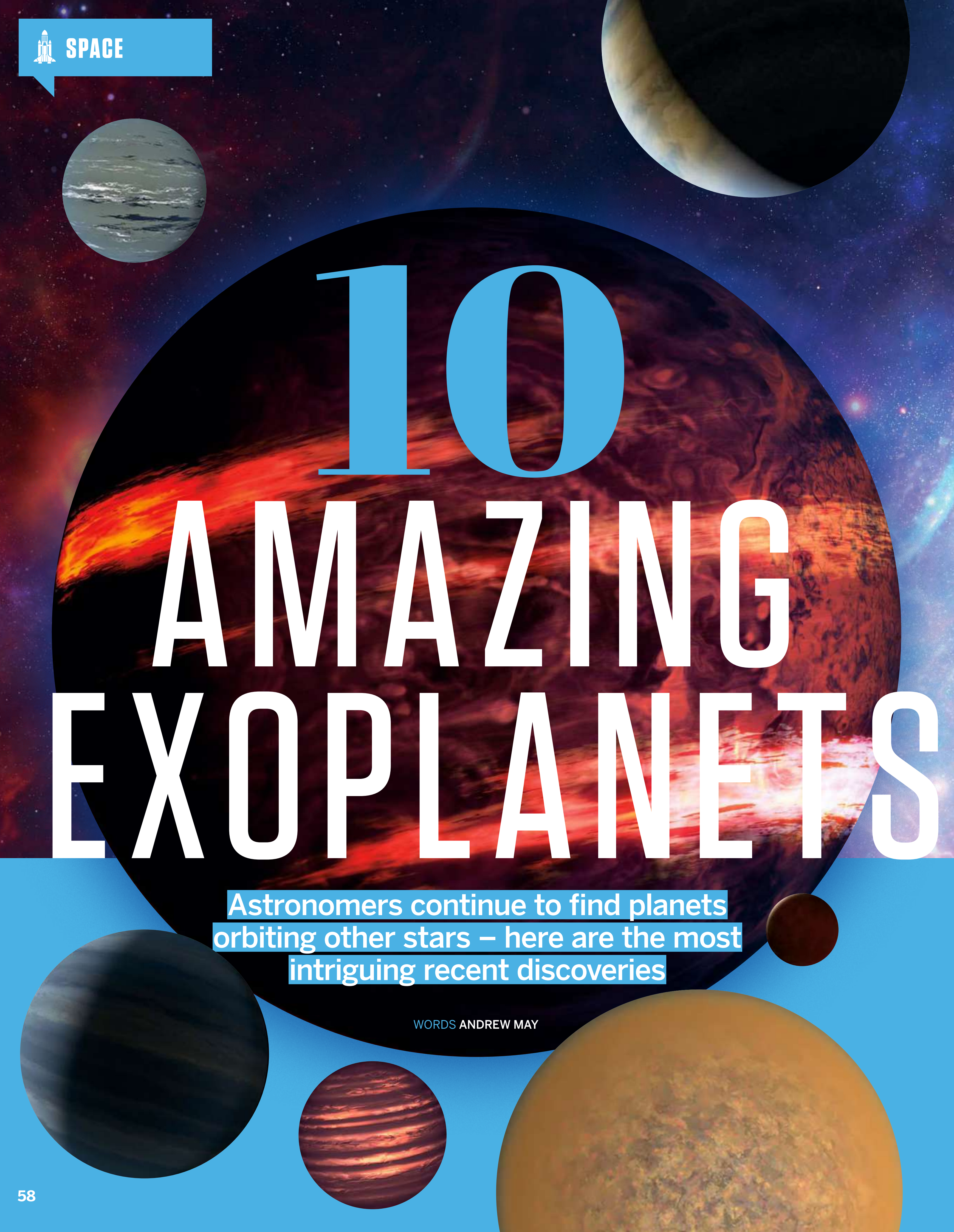
7 POWER
Two 10kWh batteries deliver power; due to its low energy consumption, it can operate for over 12 months before the batteries are depleted.

4 DEPLOYMENT
Researchers lower the Benthic Rover II from a MBARI research ship. The rover spends two hours falling to the seabed.

3 RESPIROMETER
This sensor measures the amount of oxygen that's available for marine life on the seafloor.

5 MOVEMENT
The rover will monitor carbon levels over 48 hours before autonomously moving forward ten metres to repeat the data collection.

© Alamy / Getty / NOAA Office Of Ocean / Illustration by Adrian Mann



10
AMAZING EXOPLANETS

Astronomers continue to find planets orbiting other stars – here are the most intriguing recent discoveries

WORDS ANDREW MAY

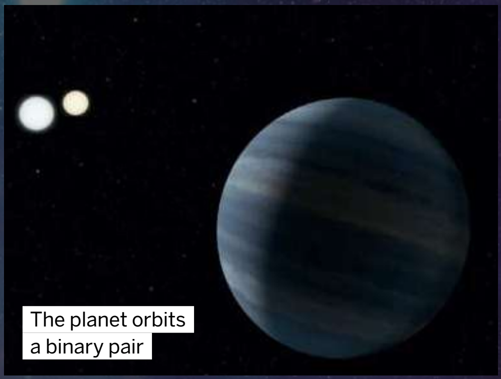
DID YOU KNOW? The discoverers of the first exoplanet around a solar-type star won the 2019 Nobel Prize in Physics

A PLANET WITH TWO SUNS

TIC 172900988 b

DISCOVERED: **2021**
DETECTION METHOD:
TRANSIT

NASA's top planet hunter at the moment is TESS – the Transiting Exoplanet Survey Satellite. This detects exoplanets by measuring the slight dimming of their host stars when a planet crosses the telescope's line of sight to them. This can be a slow process, though, because astronomers may need to observe several transits to get a full picture of the planet's orbit – and there may be months or years between transits, depending on how rapidly the planet orbits. But in the case of TIC 172900988 b, the whole process was very quick. That's because it orbits two stars, and TESS saw it transit across both of them. It also observed no fewer than three mutual eclipses between the stars themselves. Putting all this information together gave researchers everything they needed to calculate the orbit in detail.


The planet orbits a binary pair

Did you know?
Almost 5,000 exoplanets have been found to date

BROWN DWARF PLANET

CFHTWIR-Oph 98 b

DISCOVERED: **2020**
DETECTION METHOD:
DIRECT IMAGING

Brown dwarfs are often called failed stars

Brown dwarfs are enigmatic objects that are neither stars nor planets. Being 15 to 75 times the mass of Jupiter, they're unable to sustain the fusion reactions that make stars shine, yet they're found in the depths of space rather than orbiting around a star like planets do. Brown dwarfs are sometimes found in pairs which orbit a common centre of mass, but it's only recently that one was discovered with what appears to be a planet orbiting around it. The brown dwarf in question is called CFHTWIR-Oph 98, and its planetary companion – possibly as small as 4.1 Jupiter masses – was spotted in Hubble images.

HOW EXOPLANETS ARE FOUND

SCAN THE QR CODES TO SEE

DIRECT IMAGING

The most obvious way to find an exoplanet is to see it using a telescope. This isn't as easy as it sounds, because distant planets are so faint they are usually lost in the bright glare of their host stars. Nevertheless, this approach has been successful in some cases.

TRANSIT

The majority of exoplanets have been found using this method, which involves looking for a slight dimming of the host star as the planet passes in front of it. However, this can only be used if the geometry of the planet's orbit allows us to see the transit from Earth.

ASTROMETRY

As a planet orbits a star, it causes the star to wobble slightly. In principle, using a precision measuring technique called astrometry, this wobble can be observed directly. It was the first exoplanet detection method to be tried, but has only been successful in a few cases.

RADIAL VELOCITY

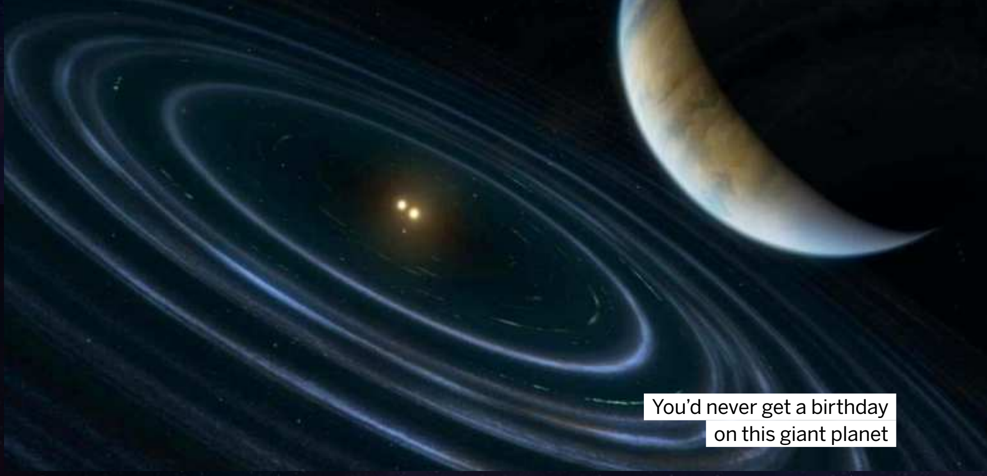
In practice, it's much easier to detect the tiny wobble caused by a planet by looking at a star's velocity rather than its position in the sky. This can be done using spectroscopy. The resulting 'radial velocity' method has been very successful.

GRAVITATIONAL MICROLENSING

This method requires Einstein's general theory of relativity. This shows how light from a distant object is bent as a star passes between it and the observer. The pattern of bending is slightly different if there's a planet in orbit.

© Getty / NASA

THE WEIRDEST ORBIT



You'd never get a birthday on this giant planet

HD 106906 b

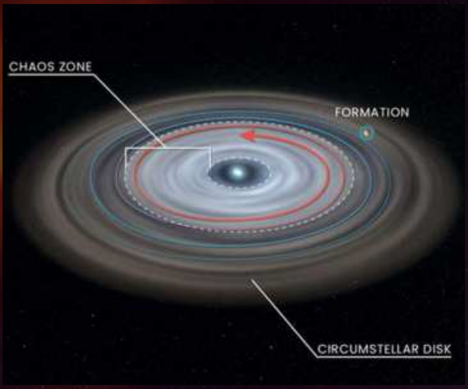
DISCOVERED: 2013
DETECTION METHOD:
DIRECT IMAGING

This huge planet – around 11 times the mass of Jupiter – is one of the few exoplanets to be discovered by direct imaging. It was originally found in 2013 by the Las Campanas Observatory in Chile, but it wasn't until 2020 that details of its orbit were worked out using data collected by Hubble. It turned out to be a truly extraordinary orbit – almost 68 billion miles out from its host binary star, which is 730 times further than the distance between Earth and the Sun. This huge orbit gives the planet an incredibly long 'year', lasting for 15,000 Earth years.

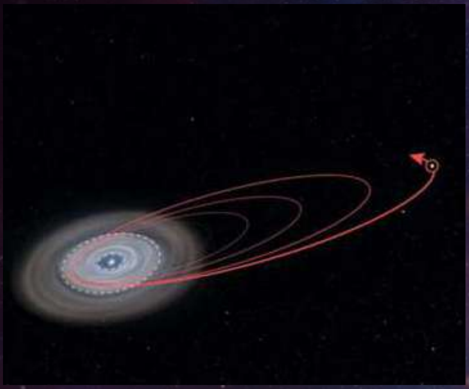
Did you know?

One exoplanet is nicknamed Hoth, after *Star Wars*' icy world

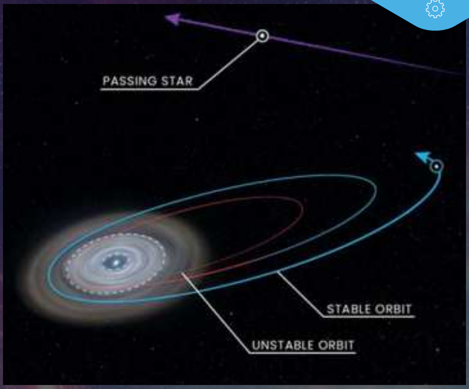
HOW HD 106906 B GOT ITS ORBIT



1 FORMATION
To start with, the planet was probably quite close to the central stars, perhaps three times as far as Earth is from the Sun. Drag forces from dust and gas would have caused it to spiral even further inwards.



2 SCATTERING
The big difference between this system and our own is the presence of not one but two stars. Their gravitational forces conspired to fling the planet outwards when it got close to them.

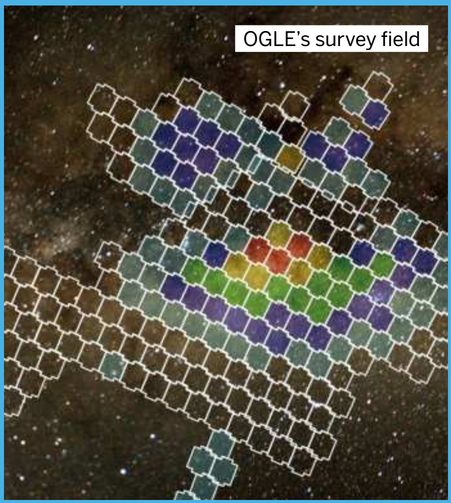


3 STABILISATION
The planet might have been ejected, ending up in interstellar space, but something happened to stabilise its present far-out orbit. This may have been an encounter with another star that passed by.

AN EARTH-LIKE MICROLENSED PLANET

OGLE-2019-BLG-0960 b

DISCOVERED: **2021**
DETECTION METHOD:
MICROLENSING



OGLE's survey field

Around 120 exoplanets have been found by the gravitational microlensing technique. Many of these bear the quirky prefix OGLE because they were detected by the Optical Gravitational Lensing Experiment. One of the most recent discoveries, OGLE-2019-BLG-0960 b, is particularly significant because it's the smallest planet yet found by this method. Its discoverers estimate it to be between 1.4 and 3.1 times the mass of Earth, and that it orbits a star smaller than our own at a distance 1.2 to 2.3 times Earth's distance from the Sun. The 'BLG' in OGLE-2019-BLG-0960 b's name refers to the particular survey field it was located in, as illustrated above.

Exoplanet HD 100777 b was named Laligurans, after the national flower of Nepal

NAMING EXOPLANETS

Assigning formal names to celestial objects is the responsibility of the International Astronomical Union (IAU). The organisation's basic approach with exoplanets is to take the name of the host star and append a lowercase letter – starting with b for the first planet discovered, then c and so on. But the IAU also runs naming campaigns around the world to assign more memorable names to selected exoplanets, many of which are based on science fiction.

DID YOU KNOW? Of all the known exoplanets, Kepler-452b and its star come closest to being 'twins' of the Sun and Earth

OUR NEXT-DOOR NEIGHBOUR

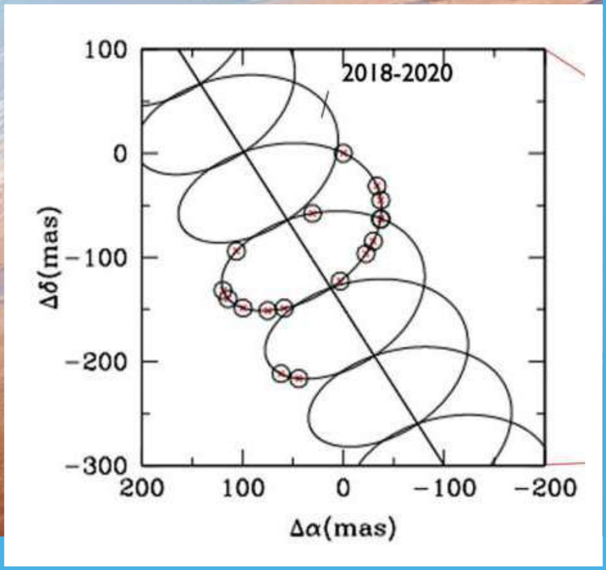
Proxima Centauri c

DISCOVERED: **2020**
DETECTION METHOD:
RADIAL VELOCITY

The Sun's nearest cosmic neighbour is the red dwarf Proxima Centauri, a mere 4.25 light years away. There was a flurry of excitement in 2016 when a planet was found orbiting this star. It was a particularly significant discovery because the planet appears to be similar in size to Earth and is located in the star's habitable zone – meaning that it might potentially harbour life. In 2020, astronomers announced the likely discovery of a second planet in the same system. But this one, dubbed Proxima Centauri c, is less likely to be habitable, orbiting so far out that it receives very little of the star's warmth.

Red dwarfs are quite volatile hosts

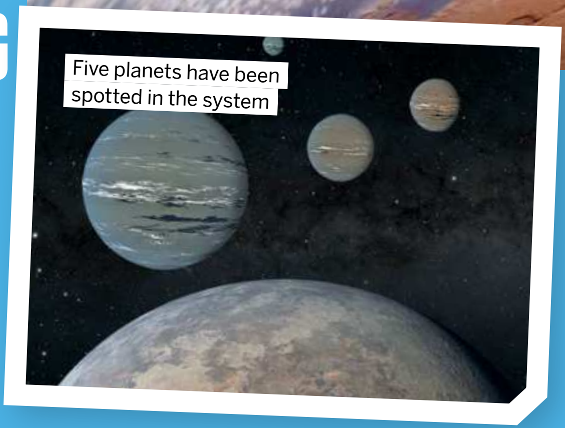
Researchers were able to infer the orbit from the data



A SCORCHING HOT SUPER-EARTH

HD 108236 b

DISCOVERED: **2020**
DETECTION METHOD:
TRANSIT



Five planets have been spotted in the system

One of the most interesting discoveries made by TESS in 2020 was a family of four planets orbiting a Sun-like star called HD 108236. Described by their discoverers as "a super-Earth and three sub-Neptunes," these cover a range of planetary sizes not found here in our Solar System. As such, the discovery team described them as "an exciting, opportune cosmic laboratory for testing models of planet formation and evolution". Of particular interest is the innermost of the four planets, the super-Earth HD 108236 b. With over three times the mass of our planet, this one orbits 22 times closer to its star than Earth is to the Sun. This gives it an amazingly short 'year' of just 3.8 days – and makes it much too hot for life. NASA estimates its surface temperature reaches a scorching 825 degrees Celsius. A fifth planet was also found in 2021.

SPOTTED BY A RADIO TELESCOPE

TVLM 513b

DISCOVERED: **2020**
DETECTION METHOD:
ASTROMETRY

Astrometry is one of the trickiest methods used to find exoplanets, involving very precise measurements of the position of a star to detect the tiny wobble caused by an orbiting planet. It's normally done using optical telescopes, but in 2020 the first astrometric detection via radio astronomy was made. This used a continent-wide network of radio telescopes stretching between Hawaii and Puerto Rico to detect a Saturn-sized planet orbiting around an ultracool dwarf star. Researchers used the measured wobble to establish that the planet has an orbital period of approximately 221 days.

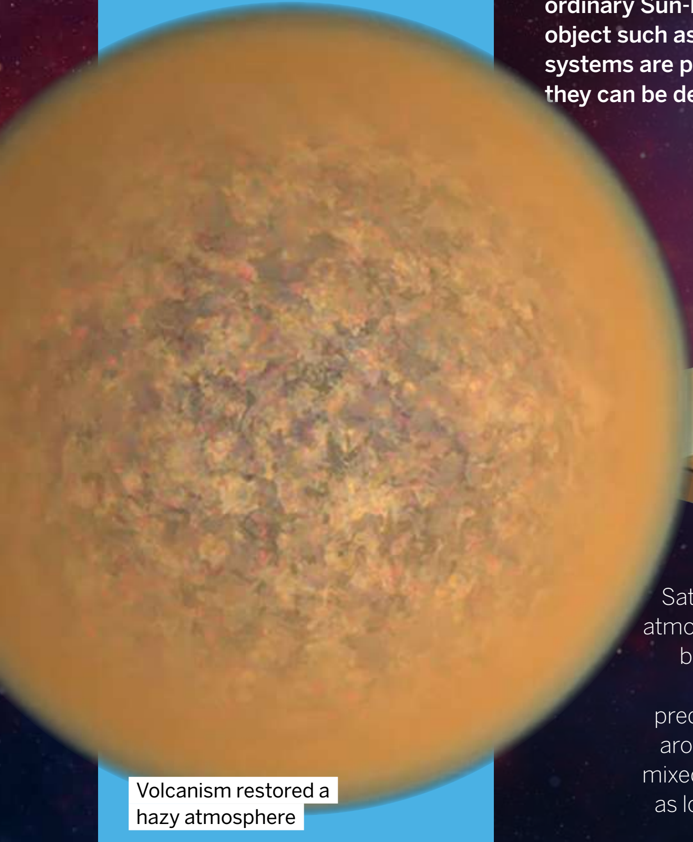
© Getty / NASA / Wiki: Vulpecula / National Radio Astronomy Observatory

A NEW ATMOSPHERE

GJ 1132 b

DISCOVERED: **2015**
DETECTION METHOD:
TRANSIT

When GJ 1132 b was discovered by Chile's Cerro Tololo Inter-American Observatory in 2015, it was hailed as the closest Earth-size exoplanet known at that time. This made it interesting enough to take a closer look with Hubble. Hubble was able to peer into the planet's atmosphere, where it made a startling discovery. Based on a combination of observational evidence and computer modelling, scientists believe it's a 'secondary' atmosphere formed by volcanic activity after radiation from the planet's parent star destroyed its original atmosphere. The new atmosphere isn't a particularly hospitable one, though, consisting of molecular hydrogen, cyanide, methane and an aerosol haze.


Volcanism restored a hazy atmosphere

The Whirlpool Galaxy, or Messier 51

MEANWHILE, IN ANOTHER GALAXY

M51-ULS-1b

DISCOVERED: **2020**
DETECTION METHOD:
TRANSIT

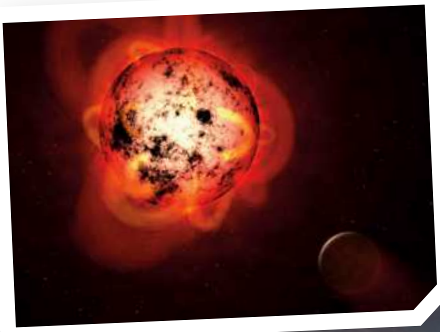
Most of the exoplanets found so far are relatively nearby in cosmic terms – generally within about 3,000 light years. That's still well within our Milky Way, but there must be countless exoplanets in other galaxies, too. The first potential extragalactic planet was discovered in 2020, lurking in the Whirlpool Galaxy (Messier 51) an incredible 23 million light years away. Called M51-ULS-1b, it was detected by the conventional transit method, but using X-ray observations rather than visible light. The planet orbits an X-ray binary system consisting of an ordinary Sun-like star and a much more compact object such as a neutron star or black hole. These systems are powerful emitters of X-rays, which is why they can be detected at enormous distances.

SMALL AND FAST

GJ 367 b

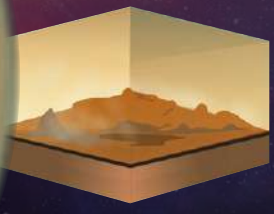
DISCOVERED: **2021**
DETECTION METHOD:
TRANSIT

One of the most recently discovered exoplanets, announced in December 2021, is also one of the weirdest. Found using TESS, it's a small world, about half the mass of Earth, and it's so close to its parent star that it completes a whole orbit in just eight hours; in other words, the planet's 'year' is just a third of an Earth day. At a distance of 31 light years, GJ 367 b is close enough that astronomers can study its properties in detail. They've worked out that it probably has a similar composition to Mercury, and an even higher surface temperature – up to 1,500 degrees Celsius on the planet's dayside. Needless to say, that's far too hot for life to exist.



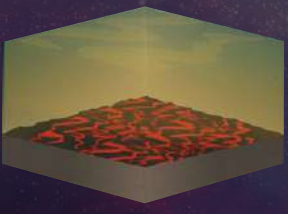
DIFFERENT ATMOSPHERES

Even within the Solar System we see atmospheres very different from our own, and exoplanets extend the range even further



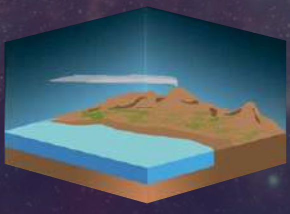
TITAN

Saturn's largest moon has an atmosphere thicker than Earth's, but it's inhospitable in the extreme. Composed predominantly of nitrogen with around five per cent methane mixed in, the temperature can be as low as -179 degrees Celsius.



GJ 1132 B

This recently discovered exoplanet is at the opposite end of the temperature range from Titan, with its surface sweltering in the region of 256 degrees Celsius. The planet's atmosphere is composed of volcanic gases, chiefly hydrogen.



EARTH

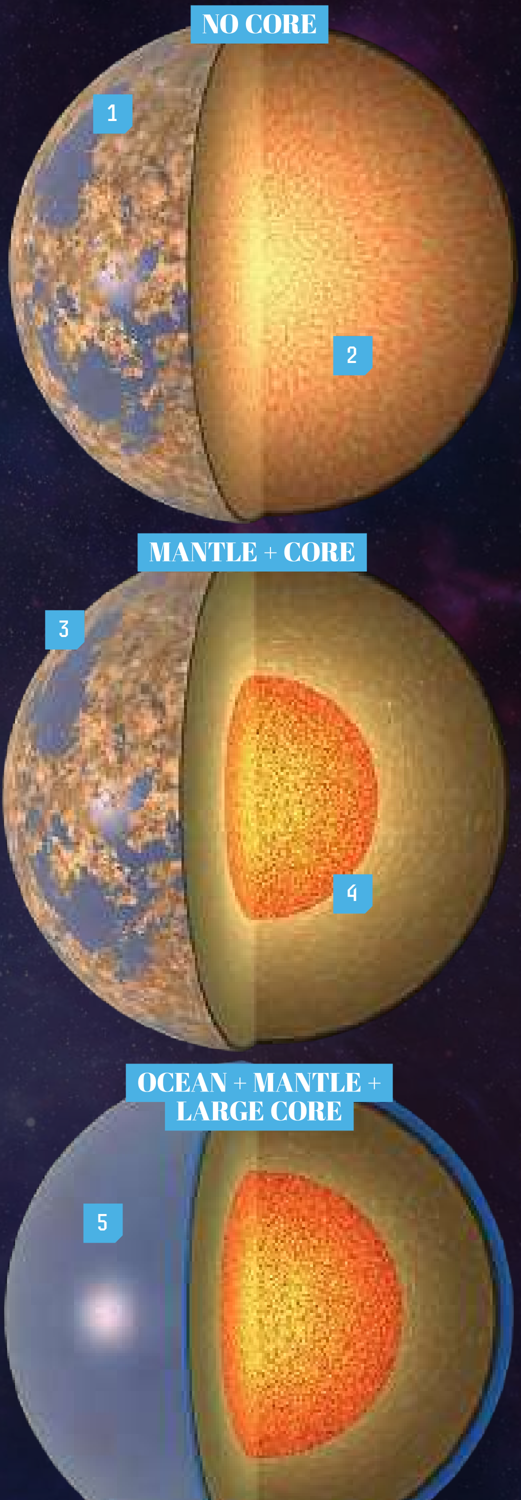
For centuries the only atmosphere known to science, Earth's is composed of around 78 per cent nitrogen, 21 per cent oxygen and one per cent other gases. The average temperature is around 15 degrees Celsius.

DID YOU KNOW? Several known exoplanets are believed to have smaller bodies – dubbed exomoons – orbiting around them

IN THE HABITABLE ZONE

The TRAPPIST-1 system has at least three potentially habitable planets

A key focus of exoplanet science is the question of habitability. This doesn't necessarily refer to worlds where humans could survive without life support, but any planet where Earth-like life might be able to develop. A major factor is the ability for water to exist in liquid form, which is only possible in the so-called 'habitable zone' around a star where the temperature is just right. The TRAPPIST-1 system – relatively close to Earth at just 39 light years away – is remarkable in that three or four of its seven known planets appear to lie in the habitable zone.



1 PLANET DENSITIES
The average densities of all the TRAPPIST-1 planets are similar to each other, but about eight per cent lower than Earth's.

2 UNIFORM COMPOSITION
We only know the average density, not the internal structure. The planets may be a uniform mix of material throughout.

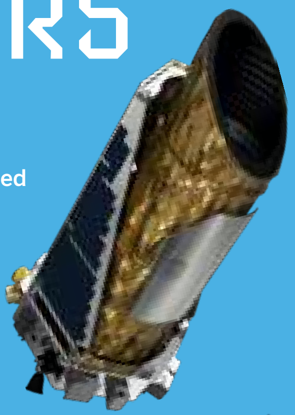
3 MOON-LIKE STRUCTURE
The planets may have a relatively simple layered structure, like Earth's Moon.

4 SMALL IRON CORE
The core would have to be proportionately smaller than Earth's to explain the lower average density.

5 OCEAN WORLD
The surface might be covered with a deep ocean of low-density water, allowing the core to be larger.

Did you know?
The planet WASP-76b is so hot it rains molten iron

THE EXOPLANET HUNTERS



KEPLER

NASA's first spacecraft designed specifically to search for exoplanets, Kepler was launched into a Sun-centred orbit in 2009, where it remained operational until its fuel ran out in 2018. Using the transit method, it discovered over 2,600 exoplanets – more than all other telescopes put together.

TESS

The Transiting Exoplanet Survey Satellite is NASA's successor to Kepler. It was launched in 2018 with the aim of searching 200,000 stars – generally nearer and brighter than those studied by Kepler – for exoplanets. As of December 2021, it has made 173 confirmed detections and identified thousands of other possibilities.

SPITZER

NASA's Spitzer Space Telescope was launched in 2003 and remained operational until 2020, occupying a similar Sun-centred orbit to Kepler. As a general-purpose infrared observatory, the search for exoplanets was just part of its mission. Even so, it made numerous discoveries, including five of the seven TRAPPIST-1 planets.

JWST

NASA's most famous telescope, Hubble, was launched long before exoplanets became a hot topic, but that's not the case with its successor, the James Webb Space Telescope. One of its main roles is to probe exoplanet atmospheres – something Hubble has already done successfully, even though it wasn't designed for it.

© NASA / Getty

INSIDE THE BLUE MOON LANDER

This lunar spacecraft is being developed for a future human colony on the Moon

Did you know?

Jeff Bezos founded Blue Origin in 2000

WORDS **AILSA HARVEY**

To date, 12 astronauts have walked on the lunar surface. While nobody has set foot on its surface since 1972, plans are in place to return people to the Moon soon. But some are envisaging steps much further ahead, including establishing a human colony on the Moon. In order to increase our knowledge of the Moon and carry out experiments on its surface, people and machinery first need to be delivered there by lunar landers. One of these currently under development is the Blue Moon lander, created by privately funded aerospace manufacturer Blue Origin. The company, which also focuses on space tourism, is owned by Jeff Bezos. Blue Moon wasn't selected for NASA's Artemis Moon missions, but Blue Origin hopes to use the lunar lander in future missions to achieve a sustained human presence in space.

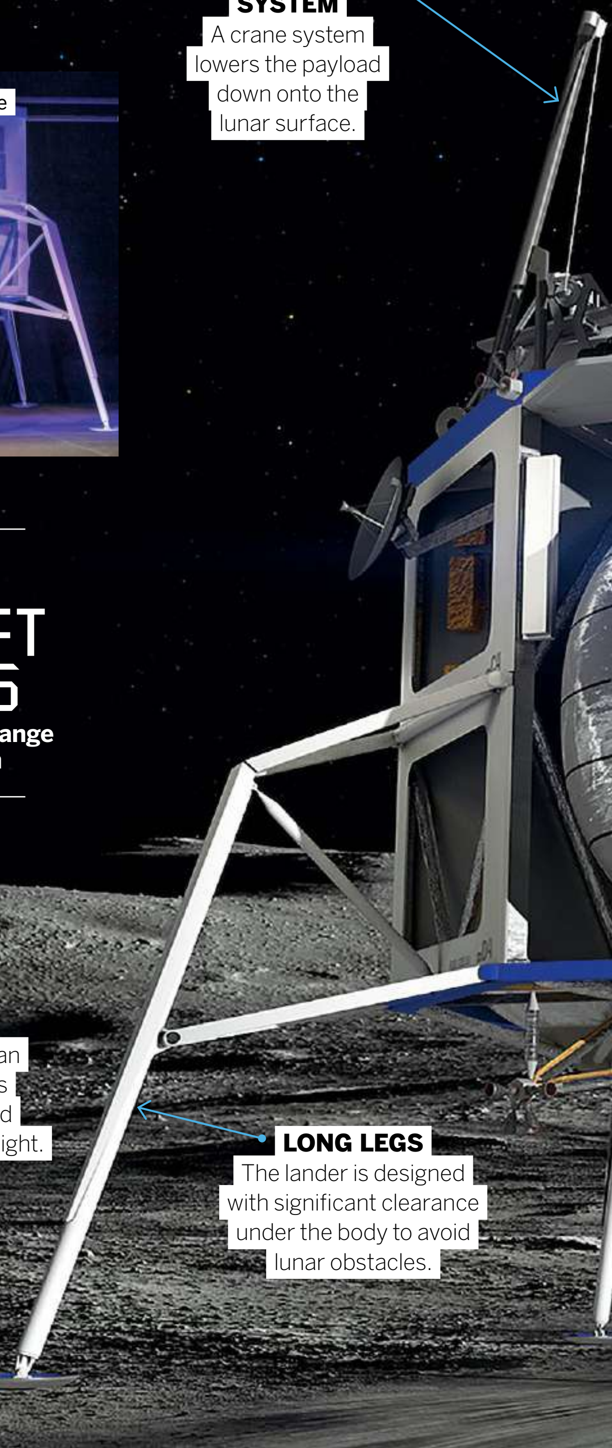
The Blue Moon lander, which entered development in 2016, uses autonomous technology to land with high precision. Equipped with lidar (light detection and ranging) sensors, Blue Origin claims that its craft is guaranteed to land within 23 metres of the preplanned landing site. Scanning the Moon, laser beams are fired at its surface to create a computerised image of the terrain. This prevents the lander from descending onto hazards and allows the flattest nearby surface to be chosen.

When in lunar orbit, the lander can release microsatellites into space. Once on the Moon, the lander will release other apparatus, such as rovers, from its top deck. The equipment that's attached to the lander can be altered based on specific mission requirements. For Blue Moon landers with a human crew – and those returning equipment and lunar samples to Earth – an ascent module can be added. This launches from the Moon to travel back to Earth.

Bezos during a talk about Blue Moon at the Walter E. Washington Convention Center

HOW THE SPACECRAFT FUNCTIONS

Blue Moon can deliver a wide range of equipment to the Moon



LOWERING SYSTEM

A crane system lowers the payload down onto the lunar surface.

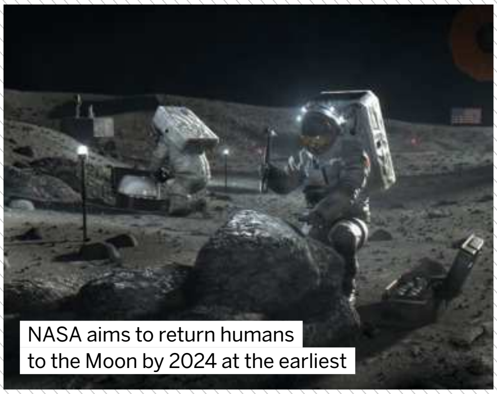
LANDING PADS

The landing pads are smaller than previous designs as the Moon's surface is now known to be solid enough to support the lander's weight.

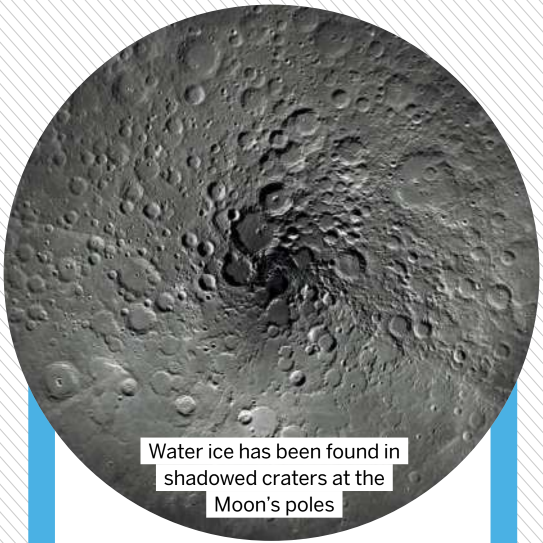
LONG LEGS

The lander is designed with significant clearance under the body to avoid lunar obstacles.

DID YOU KNOW? Engineers began work on Blue Moon in 2016, but it wasn't revealed until 2019


NASA aims to return humans to the Moon by 2024 at the earliest

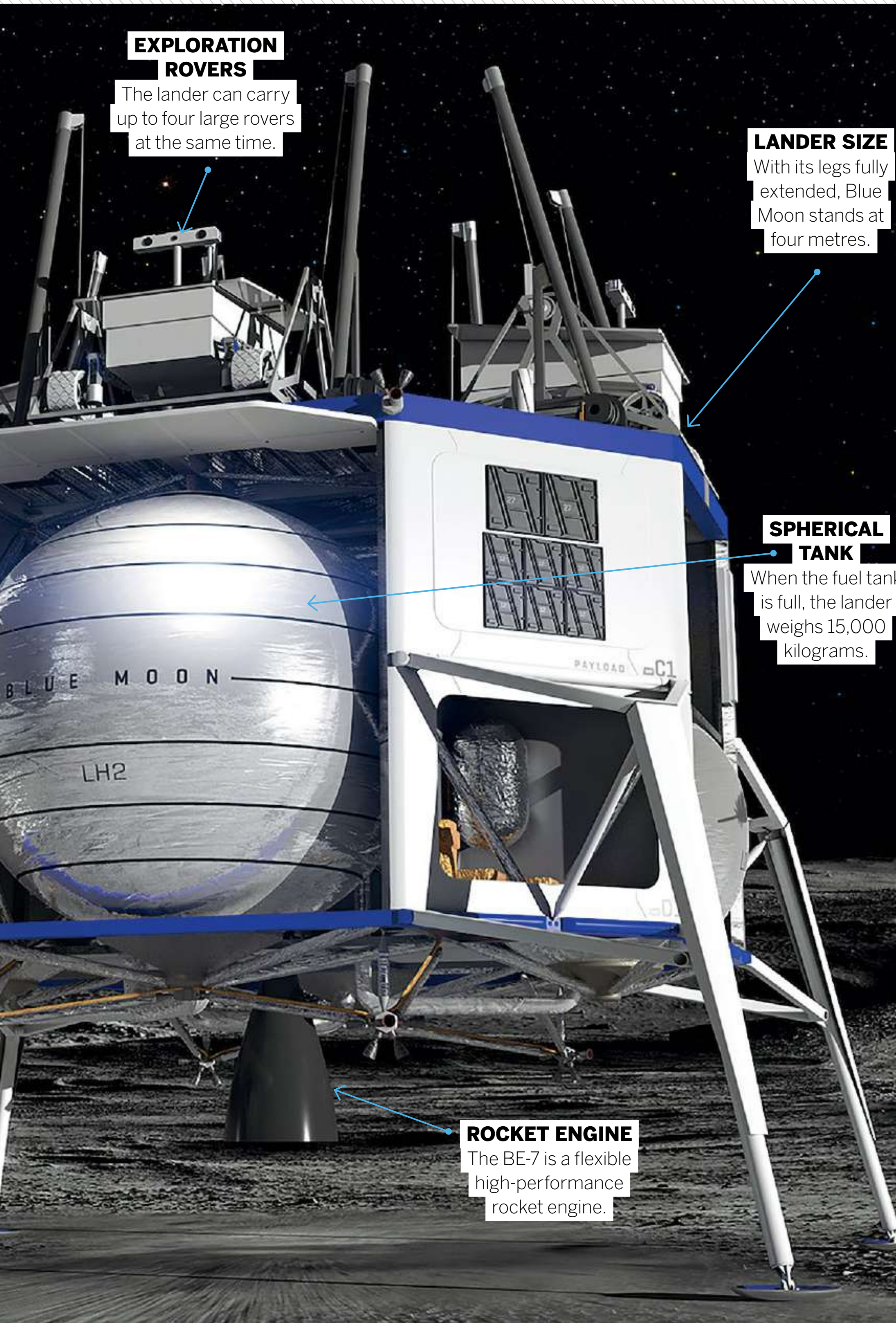
Blue Moon can land on inclines of up to 15 degrees


Water ice has been found in shadowed craters at the Moon's poles

REFUELLING IN SPACE

The Blue Moon lander uses liquid hydrogen as fuel. This propellant was chosen with future possibilities in mind. Scientists now know that there is water ice on the Moon, from which hydrogen can be extracted. By using this common element to power the lander, Bezos hopes that one day the spacecraft can be refuelled in space, utilising the Moon's natural water resources. While speaking at the JFK Space Summit in Massachusetts, Bezos said: "We know one day we'll be refuelling that vehicle on the surface of the Moon."

When separating water into its component elements by breaking its chemical bonds with thermal, electrical or chemical energy, oxygen is released. This oxygen could be used to combine with rocket fuel for combustion, or used for human breathing apparatus in space. Unlike aeroplanes, spacecraft like the Blue Moon lander can't compress fresh air from their surroundings to breathe in the cabin, so they need to carry their own supply. Making this on the Moon means the lander only needs to carry half as much oxygen during a flight to the Moon.



EXPLORATION ROVERS
The lander can carry up to four large rovers at the same time.

LANDER SIZE
With its legs fully extended, Blue Moon stands at four metres.

SPHERICAL TANK
When the fuel tank is full, the lander weighs 15,000 kilograms.

ROCKET ENGINE
The BE-7 is a flexible high-performance rocket engine.

Blue Origin has also designed a crewed alternative to Blue Moon

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CAN WE CONTROL THE WEATHER?

How existing and future technologies could help humans manipulate the climate

WORDS **AILSA HARVEY**

DID YOU KNOW? The first successful experiment to demonstrate cloud seeding took place in a lab in 1946

It may be the topic of daily small talk, but the weather and its shifting states has a big impact on the planet as a whole. In some countries, a prolonged lack of rain creates harsh, dry conditions, while others are constantly threatened by surges of floodwater. Severe weather varies drastically from country to country, but on the whole, global average temperatures are steadily increasing.

As modern technology advances and our understanding of meteorological processes grows, scientists are discovering new ways to control the weather. Instead of succumbing to nature's schedule, projects are in place to make the skies rain, remove carbon dioxide (CO_2) from the atmosphere and prevent extreme weather events such as hurricanes and flooding.

Our reasons for controlling the weather can vary from the convenient to the essential. Geoengineering is the term used to describe the manipulation of weather to combat the effects of global warming. These methods are generally split into two categories: carbon dioxide removal and solar geoengineering. The intention of geoengineering is to protect the planet. However, some scientists believe we shouldn't play with nature. The outcome may appear positive when analysed in theory, but what about any consequences that we're unaware of? Humans have played a significant role in altering Earth's climate over the decades, and many believe that to control the weather for the better, we should focus on reversing our actions. This includes using less fossil fuels and preserving plant life.

Not all weather-controlling technology is developed for the good of the planet – sometimes it's to tackle issues on a smaller scale. For example, China has been known to use its weather-modification program to control weather forecasts for events such as the Olympics. Before the Beijing Olympics in 2008, the country carried out cloud seeding to create rain in the clouds above the capital, ensuring that the rain fell before events like the opening ceremony, rather than during them.

Did you know?

Cloud seeding enhances rainfall by up to 35 per cent

CLOUD COMBAT

During the Vietnam War, the US army used cloud seeding to alter the weather. The aim was to prolong the monsoon season in Vietnam, making fighting more difficult for the enemy. The plan was named 'Operation Popeye' and meant that US troops were more prepared for the extended rainy season. Operation Popeye used rain as a weapon to destroy roads and flood rivers. To achieve this, military pilots flew over selected regions with canisters of silver or lead iodide. The canisters were ignited to release particles into the clouds. When the events of Operation Popeye were publicised, a ban was put in place by the European Modification Convention to prevent military tactics that controlled the weather.

Silver iodide canisters can be carried through clouds by a plane

RAIN ROCKETS

With cloud-seeding technology, we can shoot clouds to make them rain

1 SILVER IODIDE CARTRIDGES
Cartridges filled with silver iodide vapour are placed into a rocket launcher.

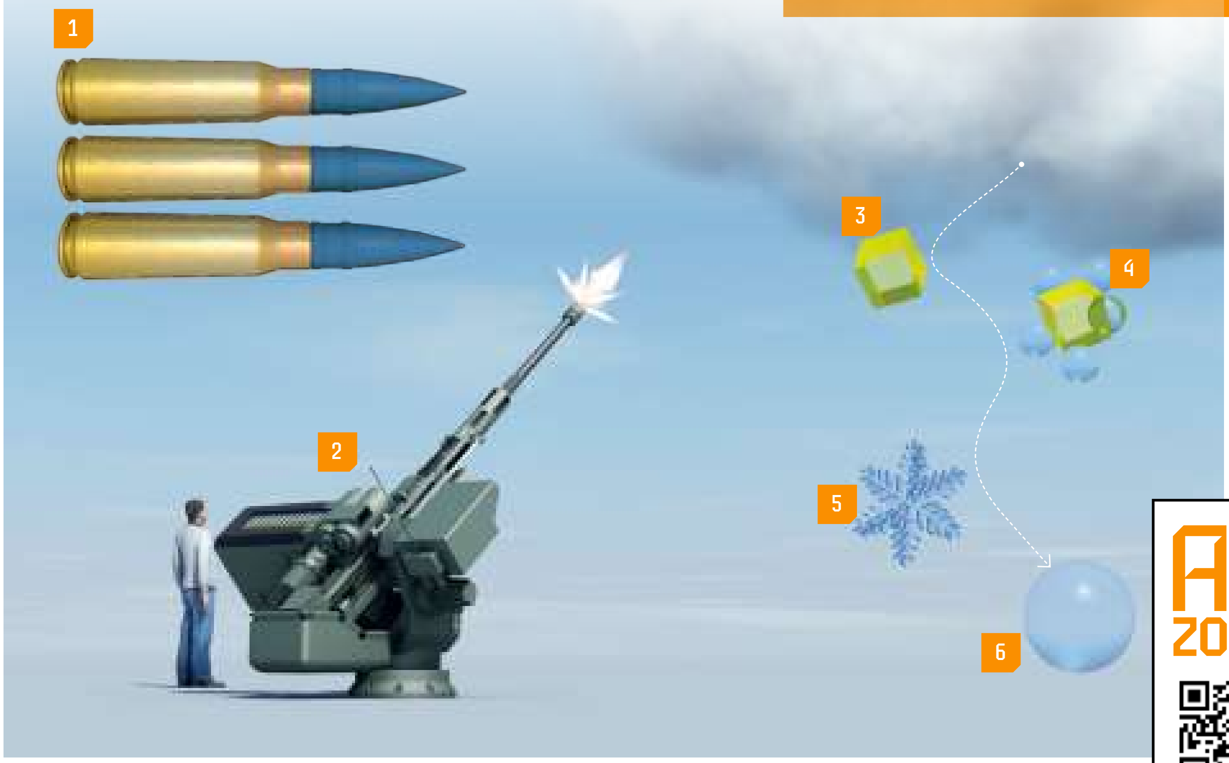
2 TO THE CLOUDS
The cartridges can be launched into the clouds via a ground-based rocket launcher or from a plane.

3 SILVER IODIDE
Silver iodide has a structure similar to ice.

4 DROPLET FORMATION
The droplets in the clouds that are too small to fall as rain surround the silver iodide.

5 ICE CRYSTALS
As the water and silver iodide combine, ice crystals form.

6 RAINDROP
The ice crystals become too heavy to remain in the air. As they fall, they melt to become raindrops.



AR zone

SCAN HERE

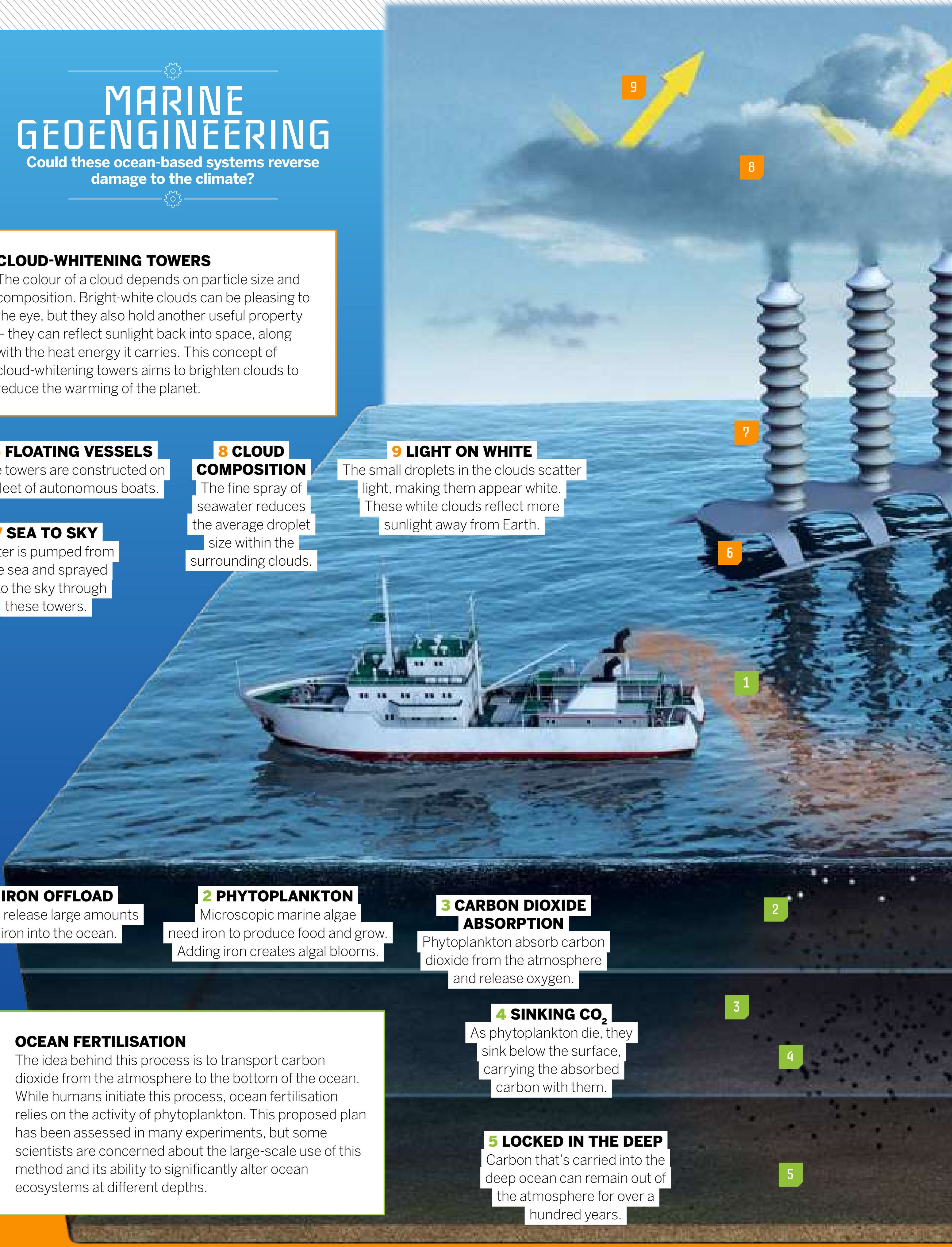
© Getty / Illustration by Adrian Mann

MARINE GEOENGINEERING

Could these ocean-based systems reverse damage to the climate?

CLOUD-WHITENING TOWERS

The colour of a cloud depends on particle size and composition. Bright-white clouds can be pleasing to the eye, but they also hold another useful property – they can reflect sunlight back into space, along with the heat energy it carries. This concept of cloud-whitening towers aims to brighten clouds to reduce the warming of the planet.



6 FLOATING VESSELS
The towers are constructed on a fleet of autonomous boats.

7 SEA TO SKY
Water is pumped from the sea and sprayed into the sky through these towers.

8 CLOUD COMPOSITION
The fine spray of seawater reduces the average droplet size within the surrounding clouds.

9 LIGHT ON WHITE
The small droplets in the clouds scatter light, making them appear white. These white clouds reflect more sunlight away from Earth.

OCEAN FERTILISATION

The idea behind this process is to transport carbon dioxide from the atmosphere to the bottom of the ocean. While humans initiate this process, ocean fertilisation relies on the activity of phytoplankton. This proposed plan has been assessed in many experiments, but some scientists are concerned about the large-scale use of this method and its ability to significantly alter ocean ecosystems at different depths.

1 IRON OFFLOAD
Boats release large amounts of iron into the ocean.

2 PHYTOPLANKTON
Microscopic marine algae need iron to produce food and grow. Adding iron creates algal blooms.

3 CARBON DIOXIDE ABSORPTION
Phytoplankton absorb carbon dioxide from the atmosphere and release oxygen.

4 SINKING CO_2
As phytoplankton die, they sink below the surface, carrying the absorbed carbon with them.

5 LOCKED IN THE DEEP
Carbon that's carried into the deep ocean can remain out of the atmosphere for over a hundred years.

AR zone

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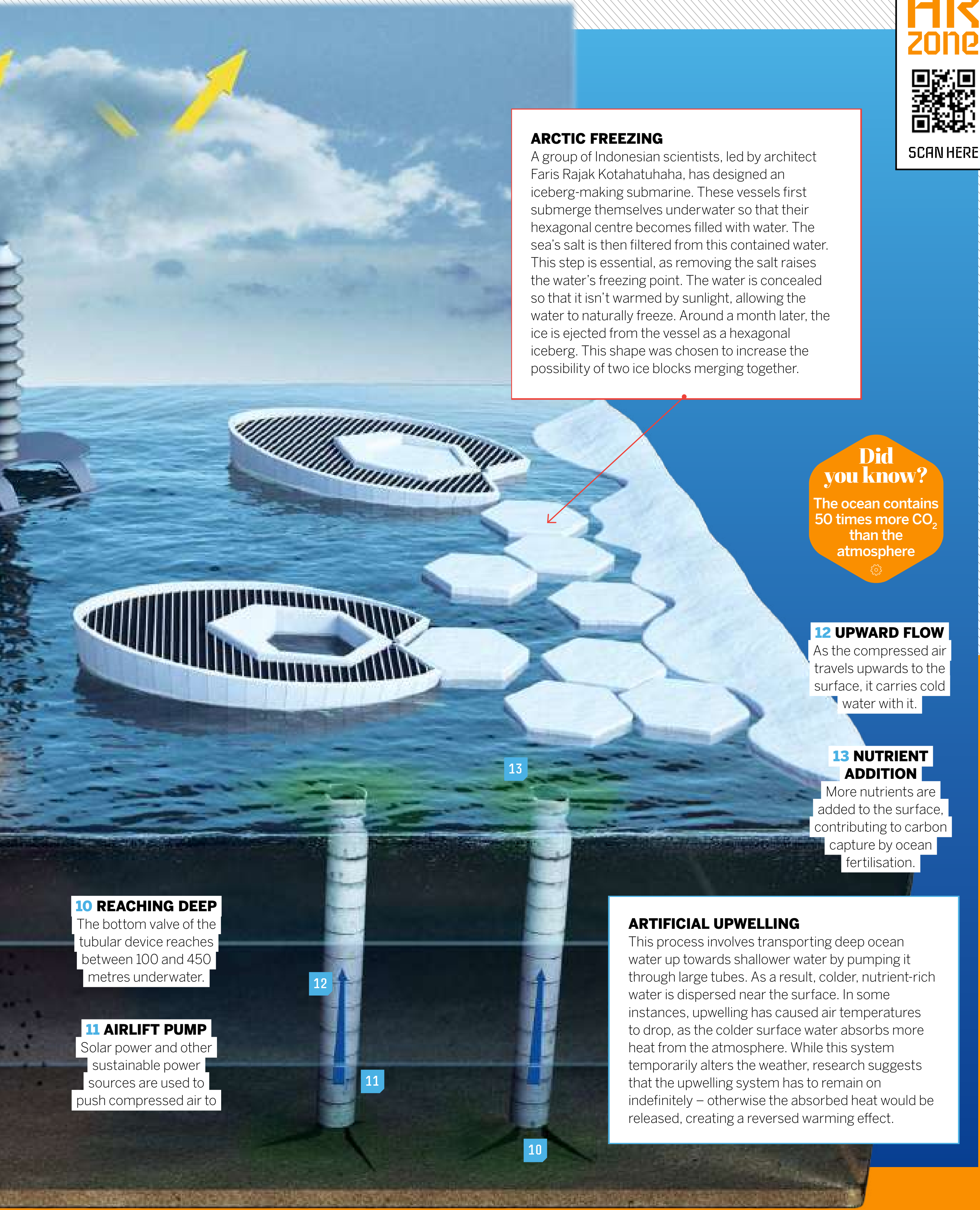


ARCTIC FREEZING

A group of Indonesian scientists, led by architect Faris Rajak Kotahatuhaha, has designed an iceberg-making submarine. These vessels first submerge themselves underwater so that their hexagonal centre becomes filled with water. The sea's salt is then filtered from this contained water. This step is essential, as removing the salt raises the water's freezing point. The water is concealed so that it isn't warmed by sunlight, allowing the water to naturally freeze. Around a month later, the ice is ejected from the vessel as a hexagonal iceberg. This shape was chosen to increase the possibility of two ice blocks merging together.

Did you know?

The ocean contains 50 times more CO_2 than the atmosphere

10 REACHING DEEP

The bottom valve of the tubular device reaches between 100 and 450 metres underwater.

11 AIRLIFT PUMP

Solar power and other sustainable power sources are used to push compressed air to

12 UPWARD FLOW

As the compressed air travels upwards to the surface, it carries cold water with it.

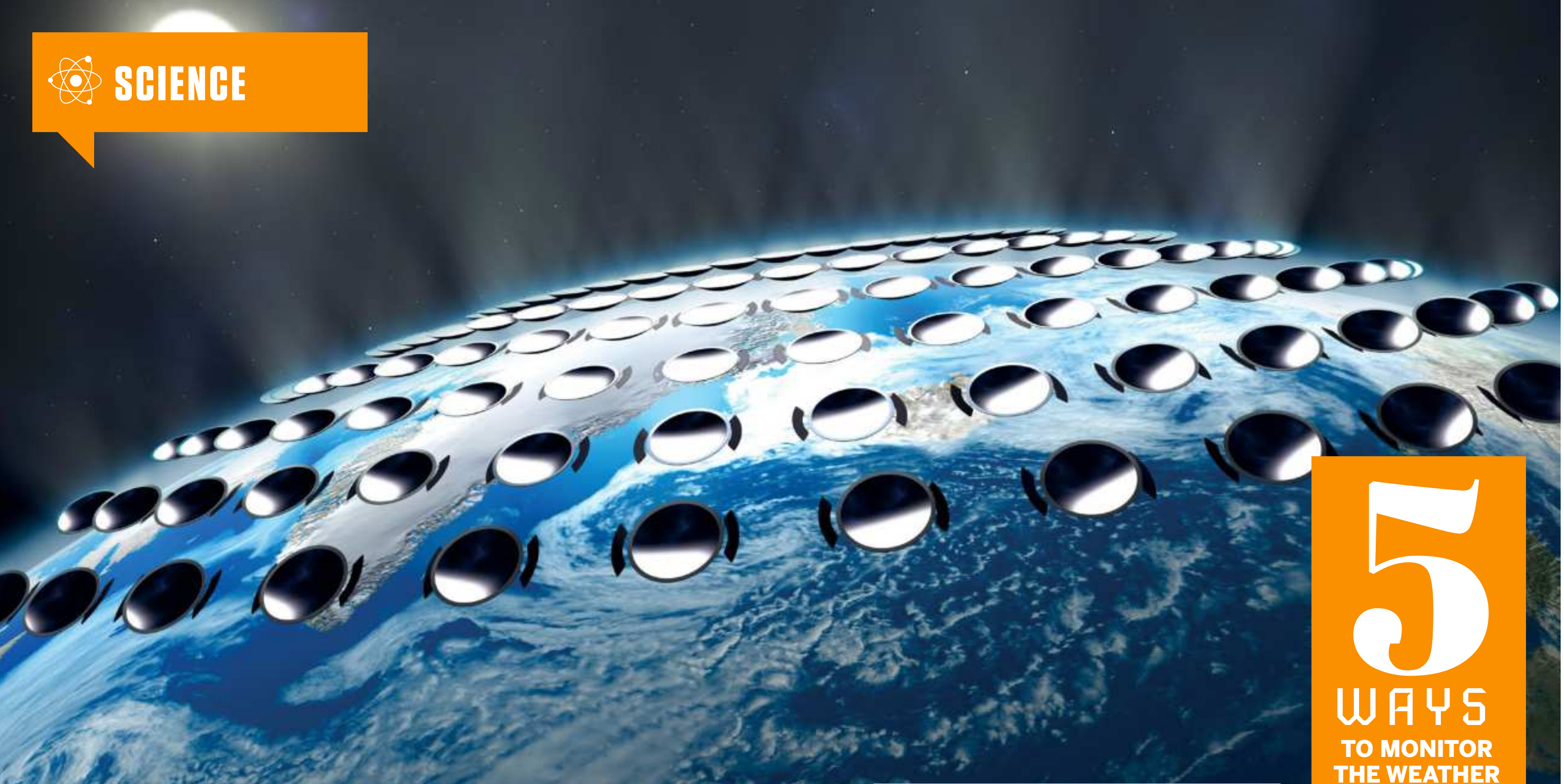
13 NUTRIENT ADDITION

More nutrients are added to the surface, contributing to carbon capture by ocean fertilisation.

ARTIFICIAL UPWELLING

This process involves transporting deep ocean water up towards shallower water by pumping it through large tubes. As a result, colder, nutrient-rich water is dispersed near the surface. In some instances, upwelling has caused air temperatures to drop, as the colder surface water absorbs more heat from the atmosphere. While this system temporarily alters the weather, research suggests that the upwelling system has to remain on indefinitely – otherwise the absorbed heat would be released, creating a reversed warming effect.

© Illustration by Nicholas Forder



PROTECTING EARTH FROM SPACE

Geoengineering projects are all created to change Earth's climate, but they're not all designed to function on our planet. Space geoengineering involves taking a large step back from Earth in an attempt to make more significant alterations. Entering space means being closer to the Sun, and so much of the geoengineering technology envisaged for Earth orbit involves manipulating the sunlight that illuminates and warms our planet.

The first idea for this type of space-based technology came from engineer James Early in 1989. His concept involved building a giant glass sheet, around 1,250 miles in width. When orbiting Earth, this glass structure would serve as a barrier between the Sun and Earth, reflecting sunlight back into space and reducing the radiation that entered Earth's atmosphere. This substantial solid structure would be incredibly expensive to fly into space, and would likely need to be assembled once there. As we currently have no long-term human presence on another planetary body, some of today's scientists have envisaged a more manageable array of smaller mirror satellites and areas of dense asteroid dust to serve as a solar barrier.

To block and deflect light away from Earth, any equipment needs to remain in a stable orbit. The most commonly proposed area to deploy such a system is at the L1 Lagrange point. This point in space is where the forces of the Sun and Earth's gravity on the object balance out, thus limited energy is needed to keep a satellite in position.

But with a location planned and multiple ideas in progress, why have none of these concepts materialised into real-life systems? Currently, the one factor that could make space geoengineering so successful is also the one that could create the greatest failure – the sheer scale of it. In contrast to the precise locations that can be targeted by a terrestrial system, altering the weather from space focuses on the entire planet.

These large-scale adjustments can't be properly tested until the mission has been funded and launched, and nobody can know for sure how the planet would respond to a sudden cooling and reduction in light.

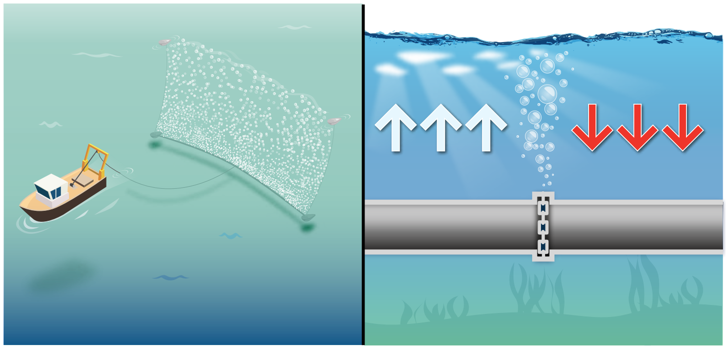
Did you know?

Cloud-seeding has been used in the United States since the 1950s

Top: Multiple small mirror satellites could be gradually introduced to space

Above: Around 13 per cent of Arctic ice is currently being lost per decade

Below: Bubble curtains may be able to prevent the warm waters that allow hurricanes to form. An underwater perforated pipe releases bubbles to carry colder water to the ocean surface



5 WAYS TO MONITOR THE WEATHER TODAY

1 SATELLITE DATA
Weather satellites orbiting Earth scan the planet with instruments which measure reflected light and infrared temperatures.

2 DOPPLER RADAR
To observe storms, this radar detects different types of precipitation, wind speed and direction and the rotation of storm clouds.

3 RADIOSONDES
Often carried by weather balloons, radiosondes measure atmospheric pressure, humidity, air pressure and wind speed.

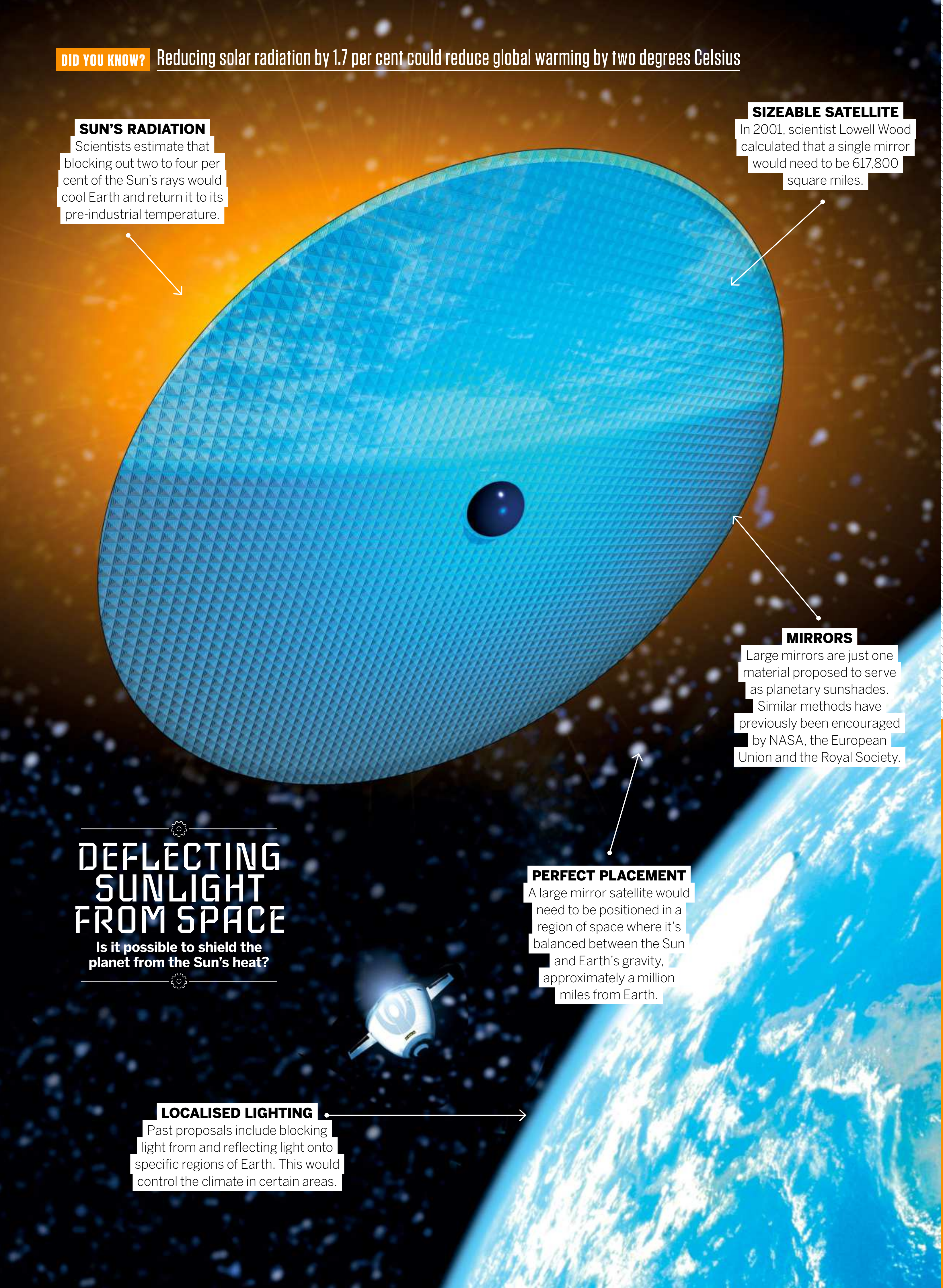
4 ASOS
The Automated Surface Observing System consists of 900 stations across the US. Every hour, these stations measure air temperature, precipitation type and amount, visibility, cloud height and wind.

5 AWIPS
The Advanced Weather Interactive Processing System analyses data from different sensors to make weather predictions. This data enables the visualisations that weather forecasters can share to save lives.

DID YOU KNOW? Reducing solar radiation by 1.7 per cent could reduce global warming by two degrees Celsius

DEFLECTING SUNLIGHT FROM SPACE

Is it possible to shield the planet from the Sun's heat?



SUN'S RADIATION
Scientists estimate that blocking out two to four per cent of the Sun's rays would cool Earth and return it to its pre-industrial temperature.

SIZEABLE SATELLITE
In 2001, scientist Lowell Wood calculated that a single mirror would need to be 617,800 square miles.

MIRRORS
Large mirrors are just one material proposed to serve as planetary sunshades. Similar methods have previously been encouraged by NASA, the European Union and the Royal Society.

PERFECT PLACEMENT
A large mirror satellite would need to be positioned in a region of space where it's balanced between the Sun and Earth's gravity, approximately a million miles from Earth.

LOCALISED LIGHTING
Past proposals include blocking light from and reflecting light onto specific regions of Earth. This would control the climate in certain areas.

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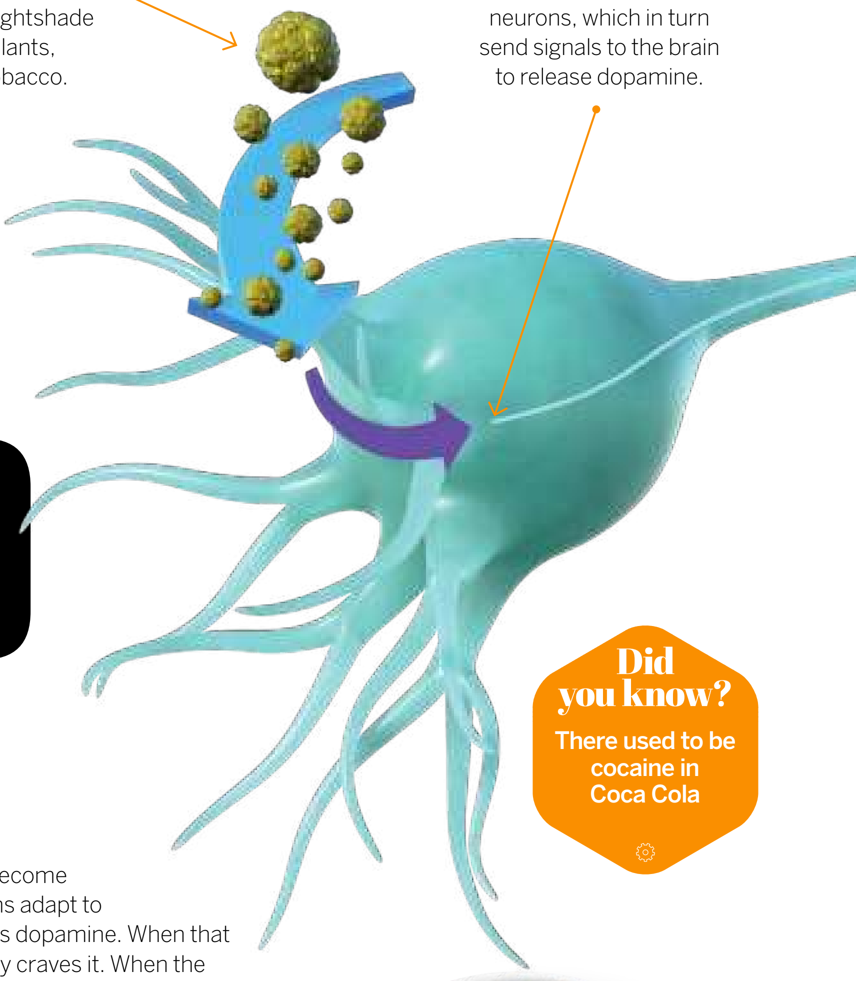
WHY WE GET ADDICTED

How our brains can be tricked into wanting more and more

WORDS **SCOTT DUTFIELD**



NICOTINE
This stimulant alkaloid is found in the nightshade family of plants, including tobacco.

NEURON
Nicotine interacts with neurons, which in turn send signals to the brain to release dopamine.

Addiction is a biopsychosocial disorder, meaning that its occurrence is a combination of a person's biology, mental health and societal factors. It's typically associated with a dependency on different harmful substances or behaviours, such as the use of narcotics, alcohol or gambling, but can also apply to overdoing anything that leads to harm.

What unites addictions is their ability to increase the levels of dopamine in the body. Dopamine is a neurotransmitter that's made in the brain. When it's released, it activates the nucleus accumbens, also known as the pleasure centre of the brain. Outside of addiction, dopamine is released during pleasurable experiences, such as getting food, watching a film or anything that brings you joy. However, this built-in reward system can be hijacked by other substances and damaging behaviours.

Some substances, such as heroin, marijuana and nicotine, mimic the presence of a chemical messenger that activates nerve cells called neurons. When activated, neurons generate electrical signals to tell the brain to release dopamine. Other substances, like cocaine or amphetamines, flood the dopamine system and cause it to release abnormally large amounts of neurotransmitters. They also disrupt the cycling of dopamine to make its presence last longer. These drugs can trigger the release of between two and ten times the amount of dopamine that is naturally produced from normal pleasurable experiences, such as eating food.

The point at which we become addicted is when our brains adapt to the presence of this excess dopamine. When that excess is missing, the body craves it. When the body experiences these false 'hits' of dopamine, over time it will begin to start reducing the level of naturally produced dopamine and also reduce the number of dopamine receptors. With low natural production of dopamine and a decrease in the number of receptors cycling it, addicted individuals will continue to use a substance or engage in behaviours that bring the brain to its newly adapted dopamine levels.

Did you know?
There used to be cocaine in Coca Cola

COFFEE ADDICTS

You might be an addict without actually realising it. In the Western world, more than 80 per cent of humans ingest caffeine on a regular basis in amounts that are large enough to affect their brains. Caffeine is a psychoactive stimulant that affects the same part of the brain as cocaine, but in a very different way. It mostly enhances concentration and improves mood, but it creates a surge in dopamine similar to other addictive drugs, but on a much smaller scale. Caffeine drinkers also experience an increase in their tolerance, meaning the more coffee they drink, the more they need to receive the same energising results.

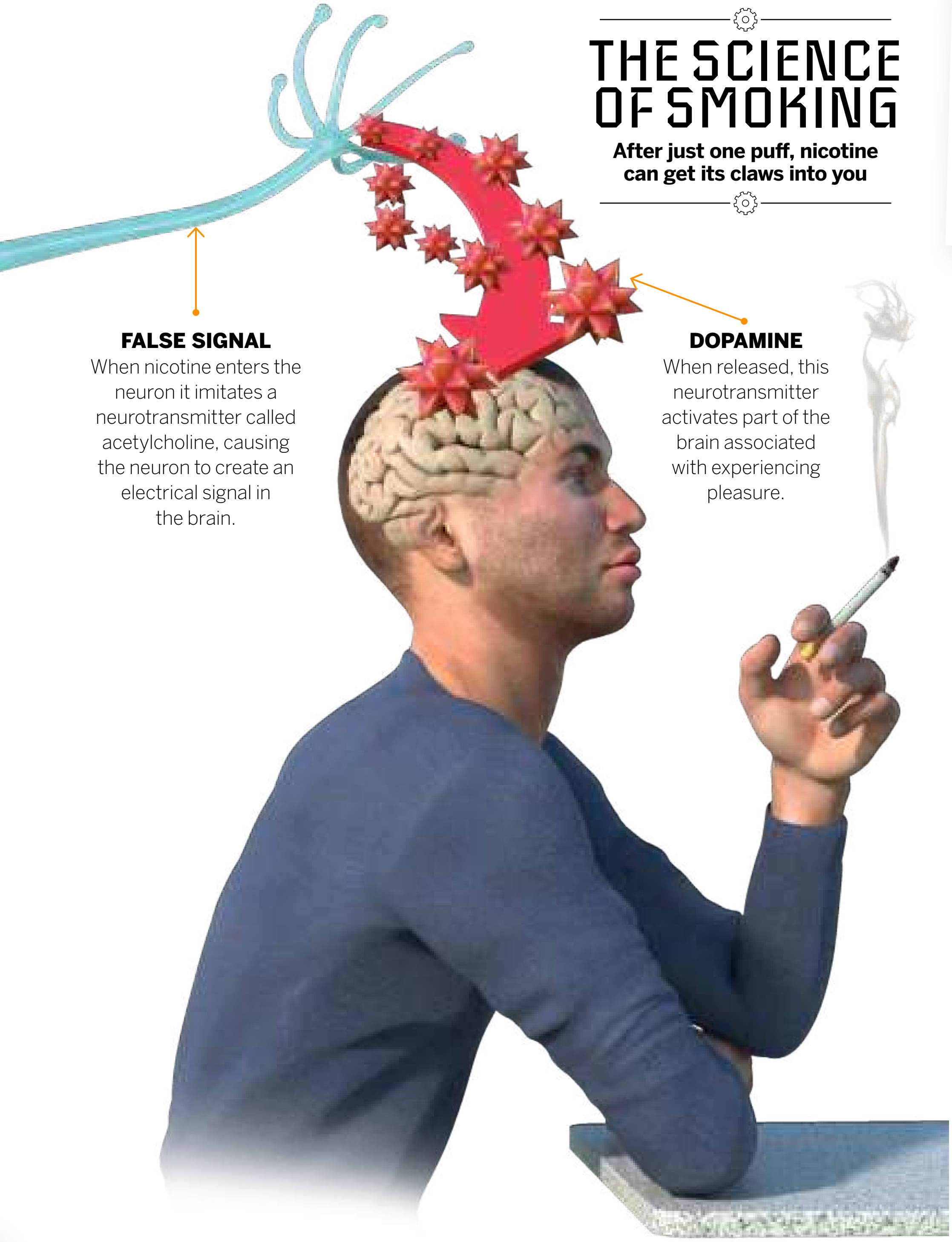
Like any other drug, the removal of caffeine-packed coffee will result in the body experiencing withdrawal, symptoms of which include headaches, fatigue and decreased motivation. However, unlike other more destructive drugs, studies have shown that quitting caffeine is much more easily achieved than quitting substances like cocaine.

DID YOU KNOW? In the US, smoking cigarettes causes more than 480,000 deaths each year

Even prescription medicines can cause addiction

THE SCIENCE OF SMOKING

After just one puff, nicotine can get its claws into you



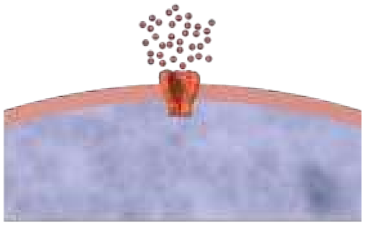
FALSE SIGNAL
When nicotine enters the neuron it imitates a neurotransmitter called acetylcholine, causing the neuron to create an electrical signal in the brain.

DOPAMINE
When released, this neurotransmitter activates part of the brain associated with experiencing pleasure.

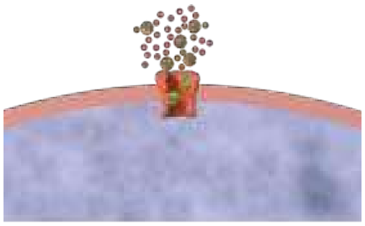
INFINITE SCROLL

It remains unclear how addictive social media is, but since the invention of the infinite scroll in 2006, social media platforms are making it harder for you to quit. The infinite scroll was invented to allow users of a social media platform to scroll down through content seamlessly and endlessly instead of clicking at the bottom of a page for more content. The switch to infinite scroll means that we're always anticipating the next piece of content, causing dopamine levels to slightly spike and then quickly fall when the next piece of content is revealed. This dopamine system will continue until you make the active choice to shut down social media or your phone's battery runs out.

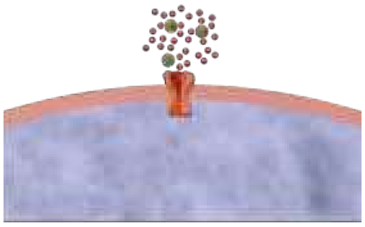
In 2021 there were an estimated 3.79 billion social media users



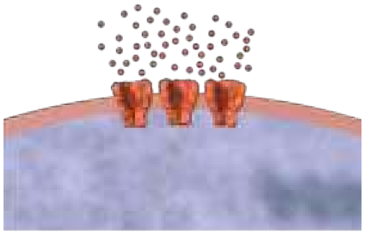
NORMAL LEVELS
Without the presence of nicotine, neurons operate normally, activated by a type of neurotransmitter called acetylcholine.



NICOTINE RUSH
Within the first few seconds of inhaling the smoke of a cigarette, nicotine binds to neuron receptors which normally bind with acetylcholine.



BURNT OUT
Once nicotine has been used up and is no longer present, receptors return to normal function.



ADDICTION
At the point of addiction, neuron receptors wait for the arrival of nicotine and the body craves the resulting rush of dopamine.

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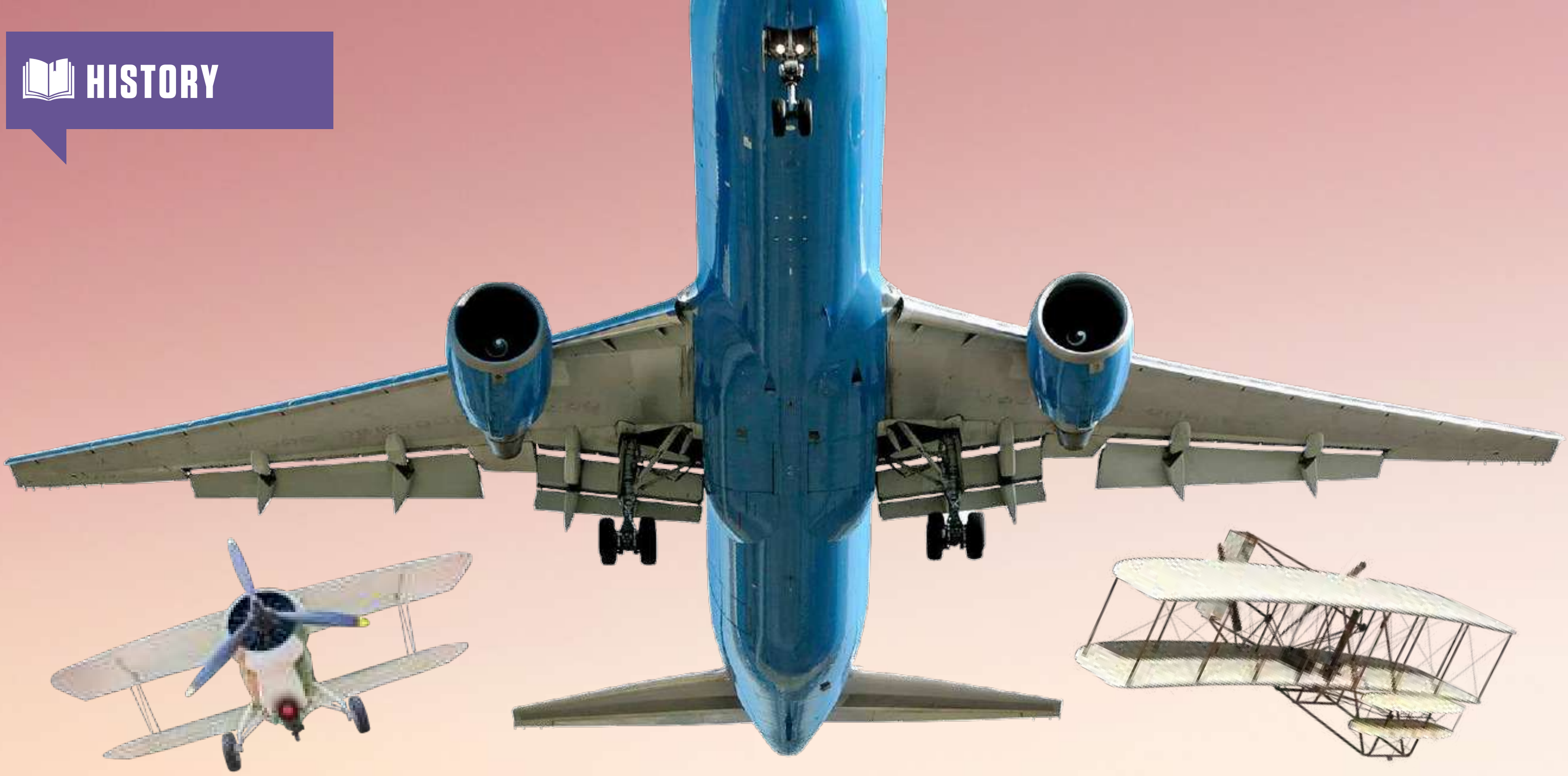


HOW HUMANS LEARNED TO FLY

Discover the evolution of human aviation, from our first forays into flight to the jets and rockets of today

WORDS AILSA HARVEY

DID YOU KNOW? The first passengers of the Montgolfier balloon were a duck, a sheep and a cockerel

Leonardo da Vinci – one of the first people to study flight – is quoted as saying: “Once you have tasted flight, you will forever walk the Earth with your eyes turned skyward.” Since the very first human flight over two centuries ago, aeronautical engineers have continued to scan the skies as they attempt to make each aircraft faster, safer, more comfortable and more efficient than the one before.

While many of the first people to study aviation were inspired by the natural flight of birds, the first substantial contributions to the field came when aircraft designers turned their focus away from the flapping motion of wings and towards more rigid structures. The first person to focus his experiments on fixed-wing aircraft was British engineer George Cayley. Before the first aeroplane was built, Cayley explained that for machines to operate successfully in the air, they would need separate systems to propel, lift and control them. He also designed the first passenger-carrying glider in 1853.

When the first wind tunnels were built in 1871, flight experiments in this controlled, fast stream of air meant that more reliable research on airfoils could take place. This is the cross-sectional shape of a plane’s wing, which needs to produce significant lift. Testing different designs in a wind tunnel was essential for the success of the first aeroplane, launched by two brothers, Orville and Wilbur Wright.

In 1901, the Wright brothers produced their own wind tunnel to test how each of their models created lift and drag. These wind-tunnel experiments became the first to measure lift and drag accurately for different wing designs.

Over 100 years on, modern aircraft undergo rigorous testing, from lightning tests that determine their protective strength to machines that bend planes’ wings to find their breaking point. Although more safety and performance tests have been put into place since the very first planes, these procedures show the continued importance of applying the science on land before taking to the skies.

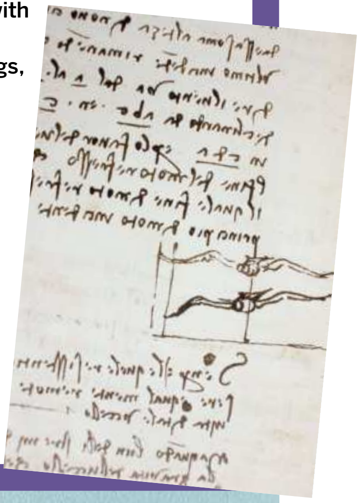
Did you know?

The busiest airport is Hartsfield-Jackson Airport in Atlanta

THE FIRST FLIGHT STUDIES

In the 1480s, Leonardo da Vinci made over 500 sketches illustrating his theories of flight. These were the first in-depth studies of flight and included concepts that are used in modern flight technology. In his drawings, da Vinci envisaged unique flying machines. He also studied the natural flight of birds as inspiration for the technology. This led to many of his designs incorporating the motion of flapping wings to create lift and propel the machines.

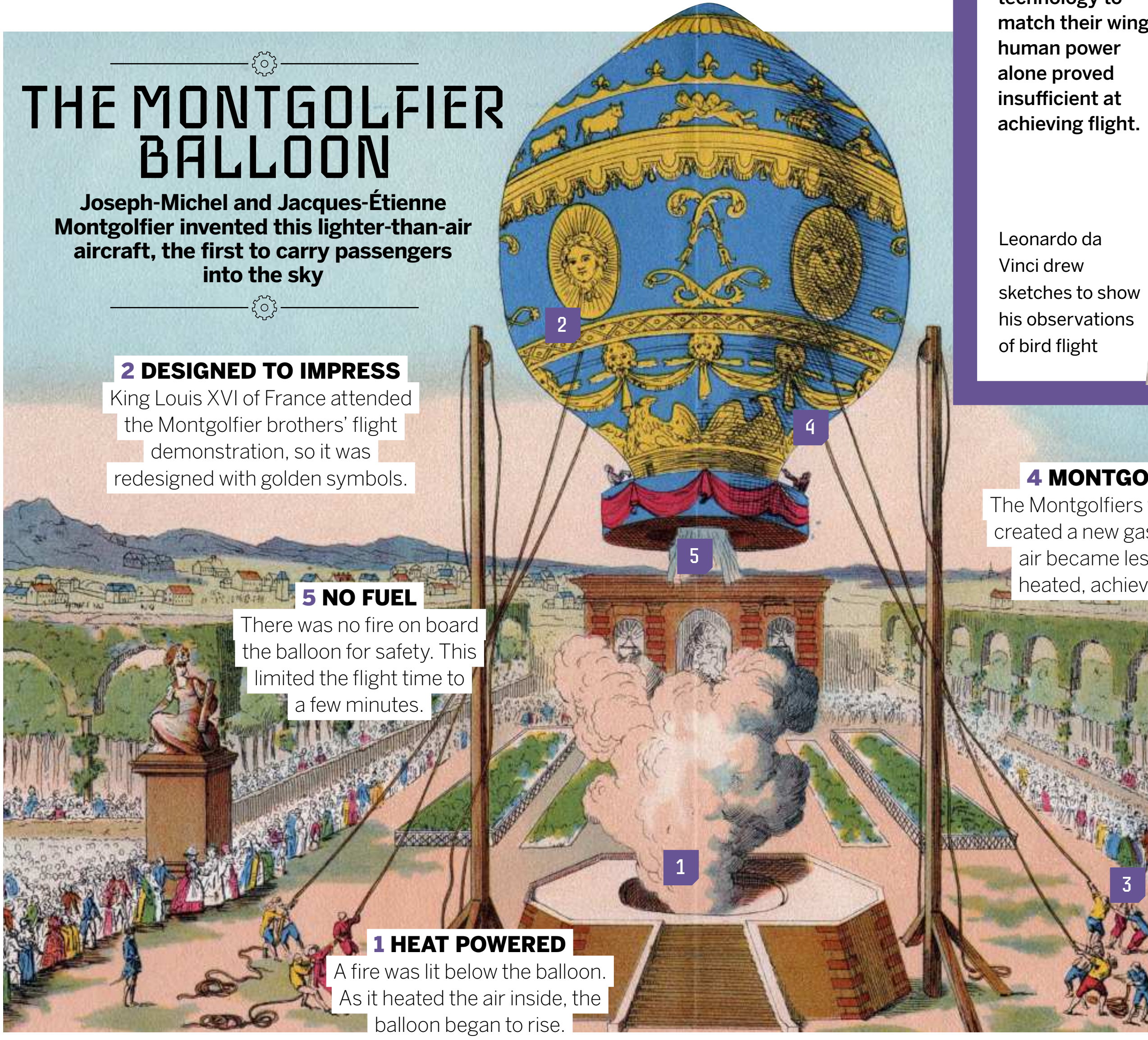
The main drawback to da Vinci’s designs is that instead of emulating vehicles that people could sit inside, they focused on giving humans the features of birds. As land animals, humans are unable to match the endurance and strength of birds flying, so even with technology to match their wings, human power alone proved insufficient at achieving flight.



Leonardo da Vinci drew sketches to show his observations of bird flight

THE MONTGOLFIER BALLOON

Joseph-Michel and Jacques-Étienne Montgolfier invented this lighter-than-air aircraft, the first to carry passengers into the sky



1 HEAT POWERED
A fire was lit below the balloon. As it heated the air inside, the balloon began to rise.

2 DESIGNED TO IMPRESS
King Louis XVI of France attended the Montgolfier brothers’ flight demonstration, so it was redesigned with golden symbols.

3 TESTING SAFELY
For the first flight with human passengers, the balloon was held in place. The balloon stayed in the air for four minutes.

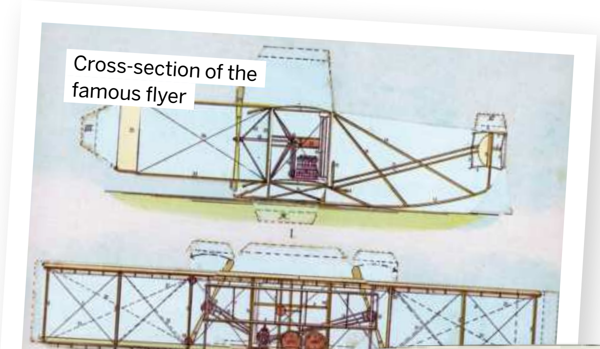
4 MONTGOLFIER GAS
The Montgolfiers thought they had created a new gas. In actuality the air became less dense when heated, achieving buoyancy.

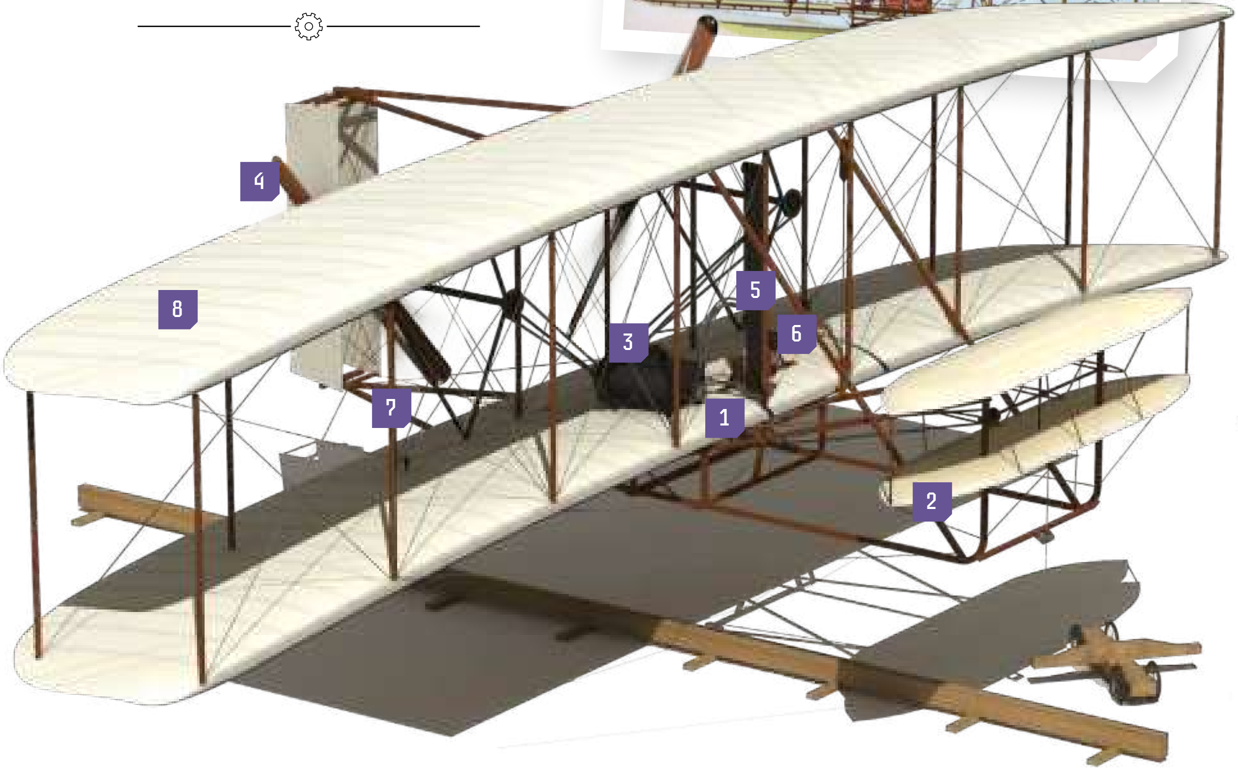
5 NO FUEL
There was no fire on board the balloon for safety. This limited the flight time to a few minutes.

© Alamy / Getty

THE WRIGHT FLYER

The first aeroplane added propulsion to existing gliders


Cross-section of the famous flyer



Did you know?

Planes can fly with just one engine and land with none

1 ROLL CONTROL The pilot lay on their front. When they moved their hips from side to side, wires attached to the wings changed the angle.

2 ELEVATOR The angle of the elevators at the back of the plane could be altered to produce lift or fly downwards.

3 ENGINE Being an alloy of 92 per cent aluminium and eight per cent copper, the 12-horsepower engine was lightweight.

4 PROPELLERS The propellers were 1.8 metres in diameter, producing thrust with a force of 600 newtons.

5 RADIATOR This cooled the engine. Hot water rose, while cool water flowed downwards near to the engine.

6 GAS TANK The 1.8-litre tank was stored inside another tank to reduce pressure.

7 AIR FRAME The straight parts of the frame were made of spruce wood.

8 WING COVER The cotton muslin was stretched over the plane's frame to achieve lift.

BREAKING THE SOUND BARRIER

When an aircraft breaks the sound barrier, it travels faster than the speed of sound, which is around 770 miles per hour in the air. The first person to do this was Chuck Yeager on 14 October 1947, flying the X-1 rocket plane. Yeager, a World War II combat fighter, was chosen to fly the experimental plane, which was built by Bell Aircraft. The X-1 was shaped like a bullet and had short, high-strength wings. The plane was flown to an altitude of 7,600 metres by another aircraft before being released.

When the plane broke the sound barrier, it had reached heights of 12,000 metres. At this altitude, air is less dense and its pressure is lower than at sea level. To break the sound barrier in these conditions, Yeager flew just over 662 miles per hour.

A photograph of the X-1 landing

HUMANS TAKING FLIGHT

1709 The first model glider was designed.

1895 The first biplane glider was flown.

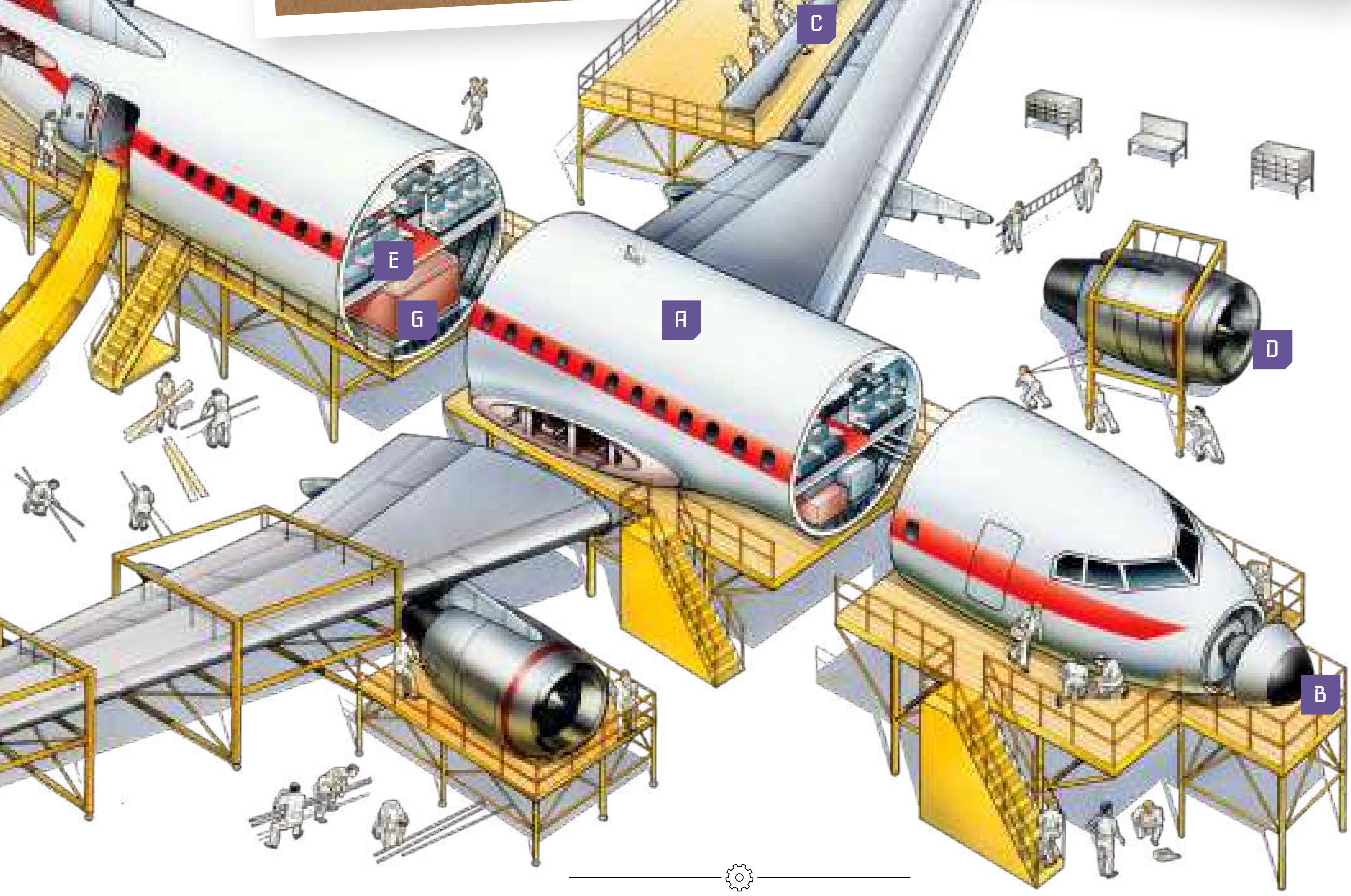
1903 The first powered flight took place.

1927 Charles Lindbergh made the first solo non-stop transatlantic flight.

DID YOU KNOW? The Wright brothers flipped a coin to determine who would be the first to test the Wright Flyer

Boeing's X-48B is an example of a blended wing aircraft

Wilbur and Orville Wright stand next to the Wright Flyer



COMMERCIAL JETS

Modern planes are designed to safely carry hundreds of passengers

A PROTECTIVE SHELL

The jet's metal-alloy skin provides high strength and low density.

B NOSE SENSORS

The nose cone holds the weather radar. This is made of materials that radar can pass through.

C AILERONS

Panels on the back of the wings can be moved up and down by the pilot to control how air moves under and over it, creating lift.

D ENGINE

Air is sucked into the plane by forward-facing fans before being compressed, sprayed with fuel and ignited. The burning gases expand and are blasted out the back of the engine.

E PASSENGER SEATS

Commercial jet airliners first appeared in the 1950s. Some of today's planes can seat up to 850 passengers.

F VERTICAL STABILISER

The highest point of the plane stops the nose from moving side to side.

G CABIN CONDITIONING

Air intakes create a flow of air into the cabin pressurisation system.

H HORIZONTAL STABILISER

This stabiliser reduces up and down motion.

5 ADVANCEMENTS FOR FUTURE FLIGHTS

1 AUTOMATION
As more driverless cars are being tested on the roads, the future could one day see pilotless planes. Auto-pilot mode can currently be set on planes, except for takeoff and landing.

2 BLENDED WING
Futuristic blended wing plane designs don't have a clear division between body and wings. Webbing around the wings creates more efficient lift.

3 TURBOELECTRIC PROPULSION
For greener and more sustainable flight, turboelectric planes could use electric generators to convert a turbine's mechanical energy into electric energy for power.

4 SUPERSONIC TRAVEL SPEEDS
Some airlines want to reduce flight times by bringing back supersonic travel. United Airlines hopes to do this by 2029.

5 IMMERSIVE ENTERTAINMENT
Virtual reality can immerse passengers into alternate worlds. This can reduce feelings of claustrophobia, especially as blended wing planes limit access to windows.

1930	1939	1970	1986	2016
The turbojet engine was invented.	The first jet-propelled aircraft was the Heinkel 178.	A Boeing 747 achieved its first commercial flight.	The first non-stop flight around the world was completed.	The first plane to be powered by renewable energy was solar powered.

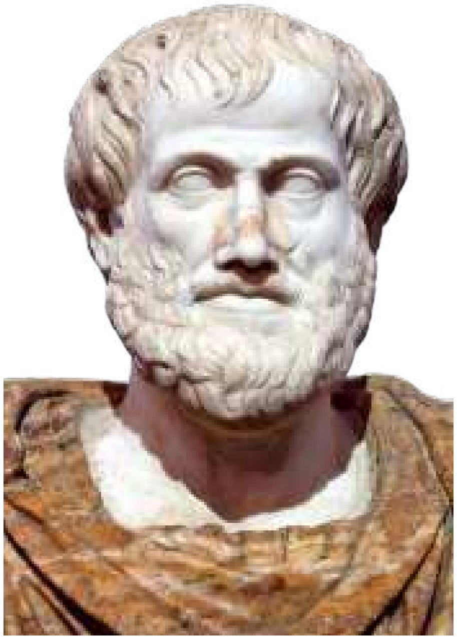
© Getty

HEROES OF SCIENCE

ARISTOTLE

How a Greek philosopher became known as the first ‘real’ scientist

WORDS **AILSA HARVEY**



Right: Aristotle was Plato’s student and colleague for 20 years

Right (bottom left): Aristotle’s birthplace is now an important archaeological site

Right (bottom right): This illustration depicts Aristotle teaching Alexander the Great

As one of the most influential Greek philosophers, Aristotle wrote around 200 works of scientific findings and other observations. His intellect was celebrated during his life, and he continues to be regarded as one of history’s greatest thinkers. The philosopher contributed to an extensive list of subjects, including science, ethics, history, logic, rhetoric, philosophy and politics. Alongside fellow Greek philosophers Socrates and Plato, Aristotle gave rise to western philosophy.

Aristotle was born to parents Nicomachus and Phaestis in a small town on the northern coast of Greece. Due to being orphaned by 13, Aristotle was cared for by his sister’s husband Proxenus. Aristotle went on to have two children of his own. He and his first wife Pythias had a daughter, also called Pythias, and he later fathered a son, Nicomachus, with his concubine Herpyllis.

Much is known of Aristotle’s thought processes and analytical skills because many of his books were preserved. One of his students, Theophrastus, took care of these books before eventually giving them to his own student, Neleus. As the significance of Aristotle’s words was already recognised, Neleus put his works into a vault to stop them becoming damaged by moisture. Eventually, the books were transported to Rome to be read by scholars. Only 31 of Aristotle’s books are known to have survived until today.

In his 50s, Aristotle spent his time as a teacher. This enabled him to spread the knowledge he had obtained during his travels and studies. One of Aristotle’s principles was to read the work produced by other intellectuals. This led to the philosopher collecting the manuscripts and writings of others. By doing so, he created one of the world’s first educational libraries for his students.

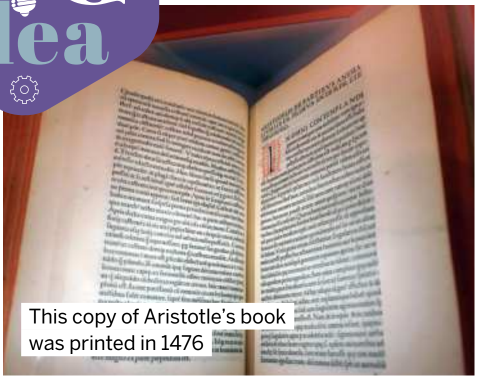
Aristotle is remembered by many as the first true scientist because of the nature in which he conducted his experiments. His preserved work shows that he used his experiments as verification of information. When his theories proved wrong, he openly admitted to the knowledge he lacked, and he always followed observation over theory when the two didn’t match up.

Much of Aristotle’s work may seem simplified to modern scientists due to the limited resources and technology of the philosopher’s time. But even in some of his less accurate work, Aristotle demonstrated a strong understanding of logic. He knew how to use logic to produce relevant scientific theories. His work taught scientists how to deduce a conclusion from a theory – a method that shapes scientific thought today.

Did you know?

Aristotle’s works were likely to have been written as lecture notes

The BIG idea



This copy of Aristotle’s book was printed in 1476

BECOMING THE FATHER OF BIOLOGY

Aristotle gained this title after his early studies in zoology. His scientific work was monumental for the human understanding of animals. Instead of theorising about different animals and the stages of their life cycles, Aristotle took an empirical approach. This included dissecting birds’ eggs during different stages of development to note changes in embryo growth. His method of classifying species is considered to be his most significant contribution to the field of biology. His work is the first known attempt to classify animals into groups based on similarities they share. In his work titled *History of Animals*, he wrote about how different animals acquired unique organs and traits based on their specific habitats.

5 THINGS TO KNOW ABOUT ARISTOTLE

1 DETAILED STUDIES
When observing animals, Aristotle carried out dissections. This was a new practice, as other Greek philosophers used only their minds to carry out work.

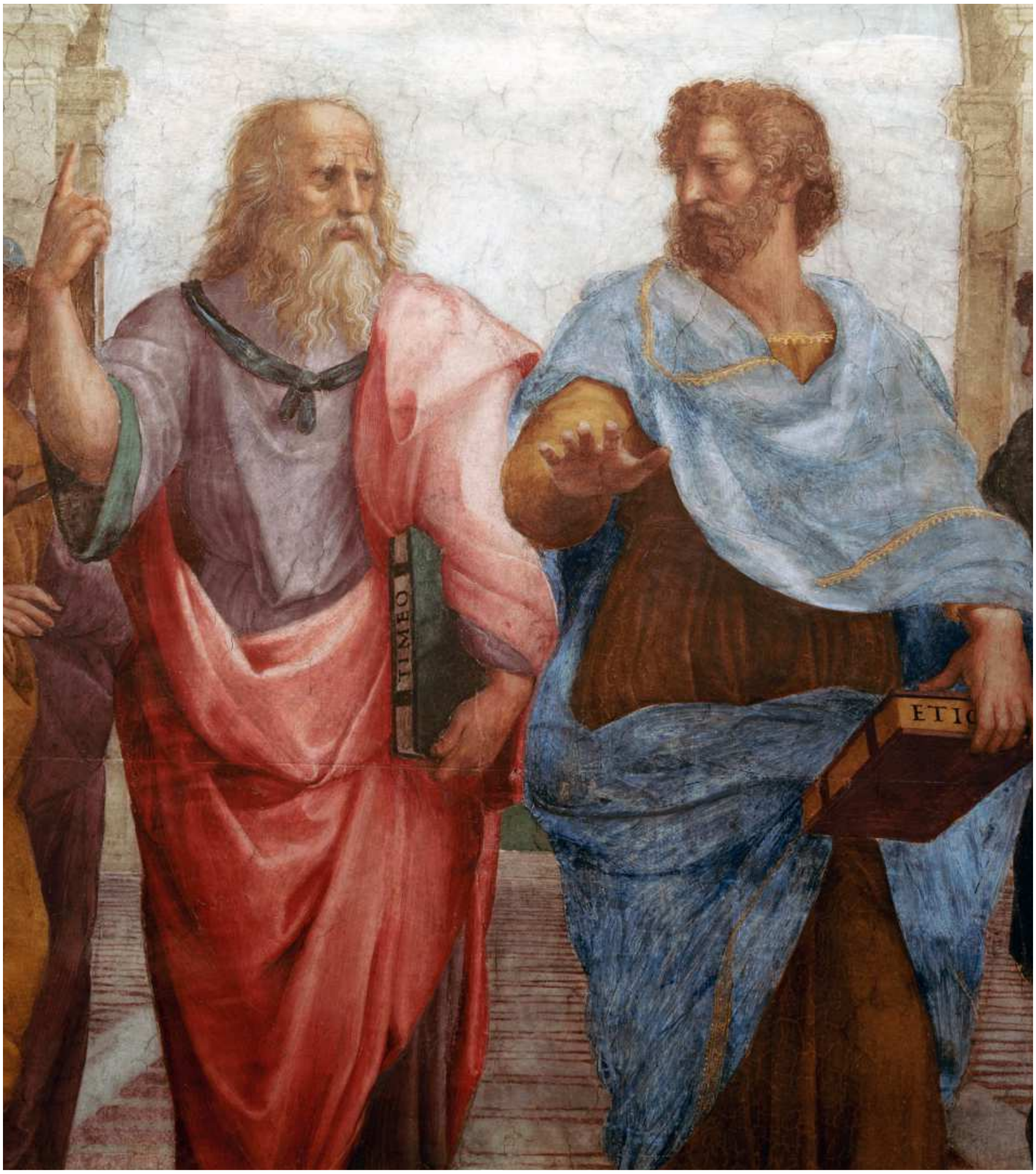
2 INTRODUCING PSYCHOLOGY
As the first to write a book specifically about psychology, Aristotle stated that it’s human nature to try to recreate feelings of satisfaction.

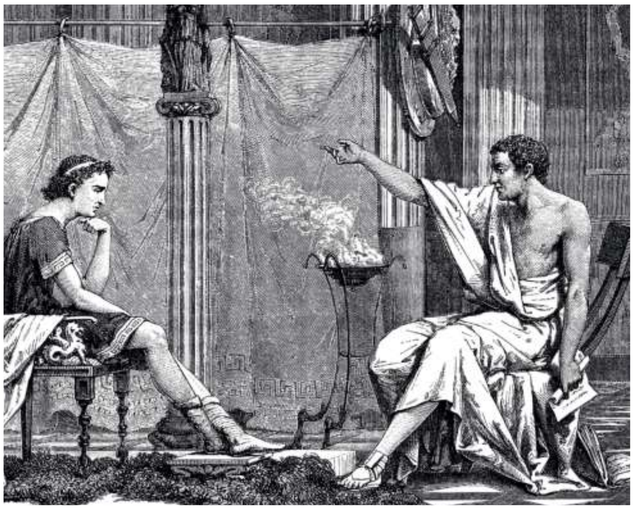
3 WRITING ABOUT ETHICS
Aristotle wrote that “regardless of the various influences of our parents, society and nature, we are the sole narrators of our souls and their active states”.

4 MANY NICKNAMES
Aristotle was called ‘the man who knew everything’. After he died he was also referred to as ‘the Philosopher’ by Thomas Aquinas, to highlight his significance, and ‘the Master’ by poet Dante Alighieri.

5 FREE KNOWLEDGE
When Aristotle opened his own school, aged 50, he made the lectures free and available to the general public.

DID YOU KNOW? Aristotle studied the classifications of more than 500 species in his scientific works





A LIFE'S WORK

From biology to literary theory, Aristotle studied numerous subjects

384 BCE

Aristotle was born in Stagira, northern Greece.

↓

367 BCE

When he was 17 years old, Aristotle enrolled at Plato's Academy in Athens.

↓

347 BCE

Aristotle travelled the coast of Asia Minor, carrying out marine biology research.

↓

343 BCE

King Philip II summoned Aristotle to tutor his son, Alexander the Great.

↓

335 BCE

Aristotle returned to Athens to set up his own school, called the Lyceum.

↓

335 BCE

He completed one of his earliest surviving works, *Poetics*, which analyses the purpose of poetry.

↓

325 BCE

Aristotle had a relationship with his concubine Herpyllis. Historians think Aristotle's lecture notes, *Nicomachean Ethics*, were dedicated to their son Nicomachus.

↓

322 BCE

Aristotle died in Euboea, north of Athens, and was buried next to his wife.

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For your chance to win, answer the following question:

Which of these is *not* a greenhouse gas?

A: CARBON DIOXIDE B: METHANE C: OXYGEN

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OFFER EXPIRES 31 MAR 2022

How much force is generated by Niagara Falls?

Lynn Erwood

Niagara Falls is comprised of two major sections, separated by Goat Island. They are exceptionally wide, and due to this they have approximately 1,833.33 cubic metres of water passing over the edge per second.

To find out how much force this generates, we can use force = mass x acceleration

The mass of one cubic metre of water is roughly 1,000 kilograms

To find the mass: 1,000 x 1,833.33 = 1,833,333.330 kilograms

F = ma

a = 9.81 metres per second squared

Therefore, the force which this water exerts is 1,833,333.330 x 9.81 = 17,985,000 newtons every second. It must be noted that this is the force which would be experienced if all of this force could be concentrated on an infinitesimal point. It's not the force you would experience per second if you stood under Niagara Falls, as you would only represent a tiny area of that which the water is hitting.

Did you know?

The falls were formed at the end of the last ice age

IF FREEZING SOMETHING CAUSES IT TO LOSE ENERGY, WHY DOES ICE EXPAND AND HAVE THE ENERGY TO BURST PIPES?

Sacha Houle

Water is different to most other substances as upon turning into ice its volume expands by roughly nine per cent, causing it to become less dense. This is due to the nature of the bonds between molecules and their shape.

Upon changing state, a substance needs to absorb or release a certain amount of energy to undergo a phase transition. For a solid turning into a liquid, this energy is needed to break the bonds in the solid, and therefore needs to be absorbed by the system. For a liquid turning into a solid, this energy is released as the bonds form.

For one kilogram of water at freezing point to change into ice, it must give off 333.55 kilojoules to its surroundings just to undergo the phase transition. This large amount of energy is normally given off as heat, which means it gives the molecules in the atmosphere more kinetic energy. However, if water is contained in a steel pipe at freezing point, the energy given off will be passed onto the molecules and bonds in the pipe, potentially causing the pipe to burst.

Do dogs see in black and white? How do we know?

Erik Mahler

Contrary to popular belief, dogs do have some colour vision, though theirs is undoubtedly different to the vision of humans. In the human eye there are two types of photoreceptors: rods and cones. Rods help us to determine differences in brightness and darkness, while cones are sensitive to colour. We have three types of cones: some are sensitive to red light, some are sensitive to green and some to blue. Dogs have more rods than humans, but less cones. Rods need less light to work, and this accounts for dogs having better night vision than humans. Humans rely more on cones, and differences in wavelength are harder to detect when there is less light, hence why we don't see very well in the dark. Dogs are said to have dichromatic vision – they can only see a part of the range of colours which are in our visible spectrum. It's thought that dogs can see different shades of yellow and blue as they have cones which correspond to being able to detect these wavelengths of light.

Why is radiation so dangerous?

Jane Valencia

There are many different types of radiation – for example, visible light is actually a form of radiation. Some are more harmful than others. There are, on average, 15,000 radioactive particles travelling through your body every second. But with all this radiation exposure, why aren't we all dying of cancer? It's not the amount of radiation which you come into contact with – as every single one of these particles has the potential to cause cancer – it's just the probability of that occurring is about one in 30 quadrillion. Only approximately one per cent of fatal human cancer is caused by these 30 trillion radioactive particles which pass through our bodies in a typical lifetime.

Ionising radiation has the energy to detach electrons from their associated atoms, therefore causing the atom to become positively charged. These charged particles are referred to as radicals and are highly reactive due to their unstable nature. Radicals are very important for certain processes in the body, such as the killing of bacteria. However, many unwanted effects, such as the mutation of cells, can be a problem. Scientists have found lots of evidence to suggest that these radicals cause mutations in cells, which can then give rise to cancer.

© Getty

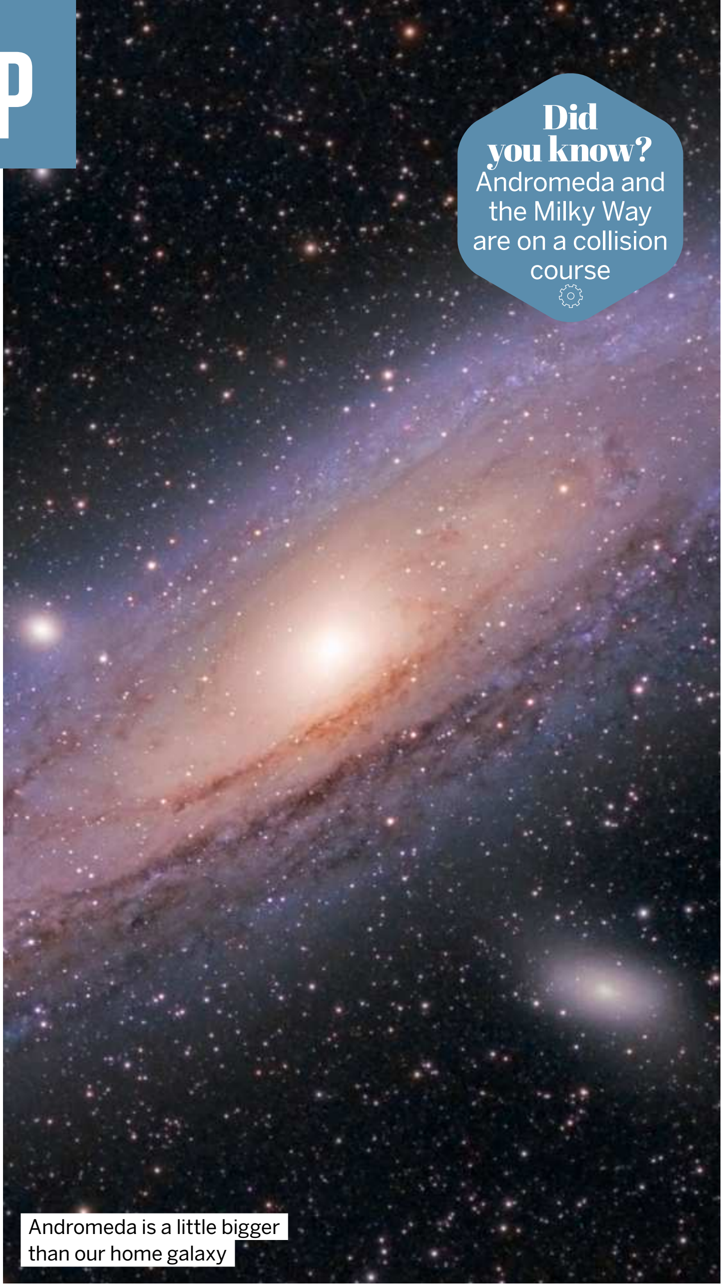
WHAT'S THE NEXT NEAREST GALAXY TO OURS, AND WHAT'S THE CHANCE OF THERE BEING ANOTHER EARTH IN IT?

Tom Sawicki

The next nearest galaxy is actually inside our own galaxy. It's called the Canis Major Dwarf Galaxy, and eventually it will be completely absorbed by our Milky Way. It contains around a billion stars, compared to the 200 billion in the Milky Way. The nearest big galaxy to ours is Andromeda, which lies around 2 million light years away.

Astronomers have discovered nearly 5,000 planets around stars other than the Sun, but most of these resemble gas giants like Jupiter rather than our rocky Earth. New telescopes have revealed more Earth-like planets, but it's still very hard to detect a small planet orbiting a distant star.

Most of the extrasolar planets so far confirmed have been in the Milky Way, as it's very difficult to spot something as small as a planet in another galaxy. But theorists think that there could be billions of Earth-like planets in our own galaxy, and a similar number in others. Somewhere out there, extraterrestrials may be waiting...



Andromeda is a little bigger than our home galaxy

Did you know? Andromeda and the Milky Way are on a collision course

Barcodes are used in many industries

How do barcodes work?

Kelsey Stevenson

Barcodes are a machine-readable way of writing letters and numbers. A laser is shone onto a barcode, and the reflected light can be interpreted by the barcode reader. There are many types of barcodes, but the ones most commonly found in supermarkets use a row of lines of different widths. The different widths represent different numbers.

In the UK, many items are coded with a Global Trade Item Number (GTIN). This allows the manufacturer to print barcodes on the packages, which can then be read in many different shops. The numbers are unique to that item. The barcode only has a number, but no product information. That's held in a database which the retailer can access at the point of sale. It also means that shops can set their own prices and change them easily without relabelling every item on the shelves.

IS EATING FISH GOOD FOR YOUR BRAIN?

Alfie Short

Yes, especially really oily fish which are rich in omega-3 fatty acids called eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Omega-3 is vital for brain growth and development and the production of neurotransmitters – chemicals which relay signals between brain cells. The body cannot easily synthesise these fatty acids, so a constant supply is very important. Just like a healthy machine, your brain needs oil, and this comes in the form of omega-3.

WHAT'S THE HIGHEST A HOT-AIR BALLOON HAS FLOWN?

Tyler Holmes

The record for a hot-air balloon is 21,027 metres. This was set in Bombay in 2005 by Indian businessman Vijaypat Singhania, who was 67 years old at the time, in a Cameron Z-type balloon. In 1960, US Air Force Captain Joseph Kittinger reached a height of 31,090 metres, but that was in a helium balloon.

SEND YOUR QUESTIONS TO: HOW IT WORKS MAGAZINE @HOWITWORKSMAG @HOWITWORKS@FUTURENET.COM HOWITWORKSMAG

Why don't whales get the bends?

Xiao Tsai

Any scuba diver is aware of the dangers of decompression. When you dive deep in high-pressure water, the air which you breathe from your tank will have the same pressure that the water is exerting. If this weren't the case then the air wouldn't come out of your tank. At a depth of ten metres the air pressure is twice that of atmospheric air pressure on land. High-pressure nitrogen from this air dissolves in your bloodstream and the water in your body. Anyone who's unscrewed a lid on a shaken fizzy drink bottle knows that bubbles start to fizz up due to the lessening of pressure. The same effect happens to the nitrogen in the bloodstream of a diver if they ascend too quickly.

How do whales and other marine mammals handle this tremendous pressure increase? They've adapted to collapse their thoracic cavity, lungs and alveolar sacs. Whales have very weak and flexible rib cages. While diving, the thoracic cavity is collapsed so no air can get in. When this collapse occurs, there's still air with high nitrogen levels present in the alveolar sac, which is the site of gas exchange. Marine mammals have adapted to this by creating a cartilage buildup in the bronchioles. This allows for alveolar collapse and storage of the air in the bronchioles. This is important because nitrogen is no longer at the site of gas exchange and cannot be absorbed into the body. The nitrogen will not fizz in the bloodstream upon ascent, therefore making them effectively immune to the bends.

Whales can dive deep without any worries

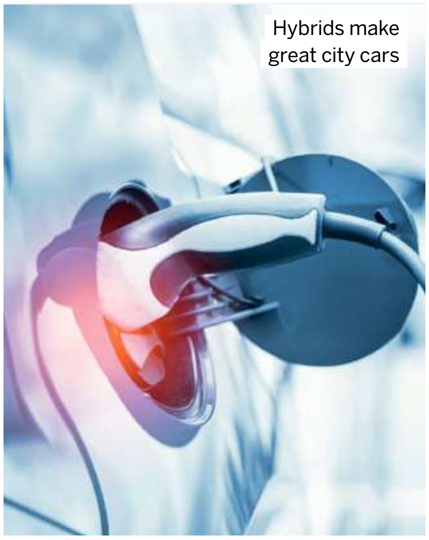
ARE HYBRID CARS REALLY ENVIRONMENTALLY FRIENDLY?

Charlotte Cockle

It depends on how they're used. They're great for city drivers, when a hybrid can rely almost fully on its electric motor, which is quiet, doesn't create any emissions, will turn off completely when the car is stationary and, crucially, gives superb fuel economy.

Drive out onto the open road, though, and the hybrid will have to fall back on its petrol engine because the electric motor simply doesn't have the power to drive the car at higher speeds, nor the energy to run for long distances. In such cases the hybrid will act just like a comparable conventional petrol-powered car, offering similar fuel economy and the same emissions. Indeed, some small modern diesel-engined cars produce lower emissions and give better economy than hybrids when driven in this way. They are usually cheaper to buy, too.

You should also take into account that the manufacturing of batteries for a hybrid car requires a lot of energy. Then, after they have reached the end of their life – which may be after just a few years – more energy is required to decommission and recycle them. This and the development impact actually make hybrid cars less environmentally friendly than the manufacturers would like you to believe.


Hybrids make great city cars

© Getty

The speed at which the galaxy is moving is almost incomprehensible

Exactly how fast is our galaxy moving?

Sarah Rentoul

Until the scientific advancements of the 20th century, it would have been virtually impossible to reach any sensible figure for the speed at which our galaxy is travelling through space. Many scientists would not have presumed the galaxy to be moving at all. This all changed, however, when the universe was shown to be expanding from a huge explosion of creation – the Big Bang – with our Milky Way and the billions of other galaxies seemingly spreading out across the cosmos. But how could we measure the speed of travel for our Milky Way? Scientists in the 1940s predicted that there should be residual evidence of the Big Bang in the shape of cosmic background radiation infiltrating the whole of space. When this was duly discovered in the 1960s, it was used as the frame of reference with which to gauge the rate at which our galaxy is speeding through the universe. It turns out to be some 1.3 million miles per hour.

HOW DO MICROWAVES COOK FOOD?

Connor Bellew

Microwaves are a form of electromagnetic wave like any other radio wave. Microwave ovens heat the water molecules inside foods, giving off heat energy that can be used by other molecules in the food to warm them up as well. This is why pasta and rice often need water added in order to heat them up.

WHY DO BATS SLEEP UPSIDE DOWN?

Elliot Hobbs

This is partly because they can't grip with their 'hands', so use their feet instead, but their feet wouldn't support their weight if they stood on them. Also, bats can't launch themselves from the ground to take off like birds do, so from a hanging position they can use gravity to their advantage to get airborne, as well as being protected from predators.

Goldfish are a popular pet

Do fish really have a three-second memory, and how do we know?

Ellis Dixon

This is a myth, with various studies disproving the commonly held belief. In January 2009, researchers from the Technion Institute of Technology in Israel taught fish to respond to a sound that meant feeding time in captivity. The fish remembered the sound months later having been returned to the wild, returning to a certain spot for feeding.

Did you know?

Tish the goldfish lived for an incredible 43 years

HOW DO PAINKILLERS CURE HEADACHES?

Kieran King

There are two key types of painkillers that are commonly used. The first include ibuprofen and paracetamol, which block the body's 'prostaglandins' – chemicals that produce swelling and pain – at the source of the pain, reducing swelling in the area and reducing the intensity of pain. These 'aspirin medicines' are used frequently for mild to moderate pain, but they can only work up to a certain intensity of pain. There are different types of painkillers within this group, such as anti-inflammatory medicines like ibuprofen, commonly used to treat arthritis, sprains and strains. Aspirin can be used to help lower the risk of blood clots when used in a low dosage, as they thin the blood. Paracetamol is an analgesic, used for reducing pain and lowering a temperature.

The second type of painkillers include morphine and codeine, which block the path of pain messages in the spinal cord and the brain. This is for much more severe pain. As both types of painkillers use slightly different methods to treat pain, they can be combined, such as in co-codamol, which blends codeine and paracetamol.

Mild painkillers don't need a prescription

Why don't forklift trucks tip over?

Oliver Kerr

Unfortunately, they do. Used mainly in warehouses to lift and move heavy loads, forklifts are very dangerous; every year there are over 8,000 accidents involving them. The average weight of a forklift is about three times that of the average car, and this weight is mainly distributed at the rear to counterbalance the load on the forks at the front. The front wheels, meanwhile, act as a fulcrum.

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THE LIBRARY

The latest book releases for curious minds

NORSE MYTHS

GODS, GODDESSES, HEROES AND MONSTERS BROUGHT TO LIFE

AUTHOR **MATT RALPHS**
ILLUSTRATOR **KATIE PONDER**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£16.99 / $21.99**
RELEASE **OUT NOW**

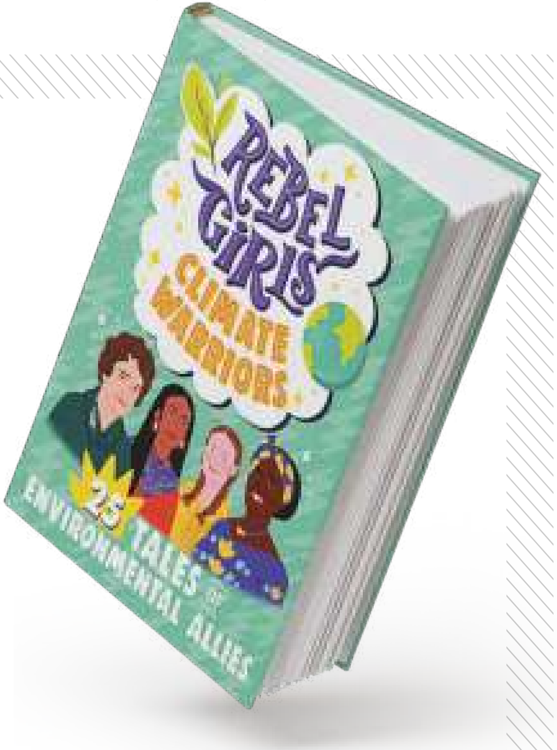
Norse mythology is pretty trendy right now, what with the Marvel Cinematic Universe popularising a handful of characters from ancient Viking lore in big-budget cinema. Names like Thor and his hammer Mjölnir, the mischievous Loki and the world of Asgard will be familiar to millions of Marvel fans. If the movies are a toe-dip into the icy waters of Scandinavian legend, Matt Ralph's *Norse Myths* is an ice dive into these wild and frequently weird stories.

The author prefaces the book by telling us that although these tales were first written in the 13th century, like most myths they were passed down by word of mouth across generations of Vikings for an unknown number of centuries before they were committed to paper. They have evolved over hundreds of years of retellings, but they've lost none of their character and weird allegories along the way: Ralphs tells us about how at the beginning of everything, frost giants emerged from a world of ice called Niflheim and a giant cow licked the salty ice to create a god called Buri, who married a giant and gave birth to other gods – his grandson was Odin, the famous god of wisdom, death and a few other things.

These stories don't get any less odd, or charming, as we learn about the nine worlds and their inhabitants on the giant ash tree Yggdrasil. We get a real idea of how the Vikings viewed events or objects that they had no scientific understanding of through metaphorical ideas. Perhaps the melting of the ice in Ginnungagap, with life springing out of it, was how the Vikings interpreted the glaciers retreating from their homelands in times gone by.

> **These stories don't get any less odd, or charming, as we learn about the nine worlds and their inhabitants**

In the last section, Ralphs gives us a bit of much needed background to the Vikings, their beliefs and traditions for a fuller understanding of the origin of these myths. It's a fantastically illustrated book too, conveying all the wonder, horror and awe that these people must have experienced in their chilly but beautiful world when they dreamt up these stories.



REBEL GIRLS: CLIMATE WARRIORS

25 TALES OF WOMEN WHO PROTECT THE EARTH

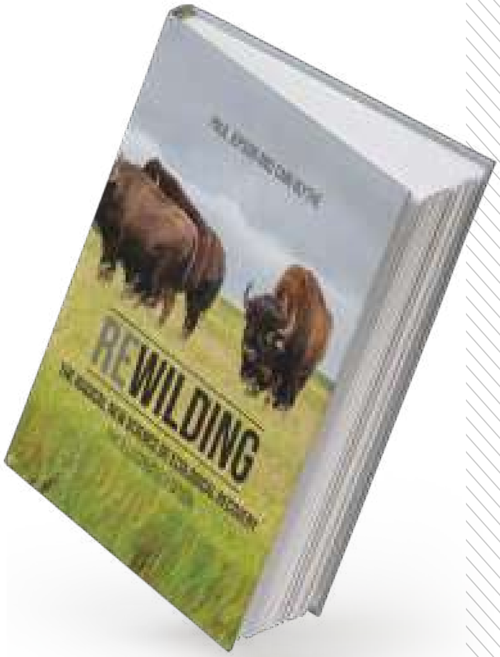
AUTHOR **REBEL GIRLS**
PUBLISHER **REBEL GIRLS INC**
PRICE **£6.99 / $8.99**
RELEASE **14 APRIL**

From well-known trailblazers such as Greta Thunberg and Danni Washington to lesser known but equally dedicated environmental champions like Kristal Ambrose and Lucie Pinson, this book showcases the hard work of some of the best and brightest women fighting against climate change. Although the stories of these women are just snippets of their work and backgrounds, some examples have accompanying QR codes that link to bonus audio stories for more information. *Rebel Girls: Climate Warriors* is not only a celebration of the achievements of these amazing activists and scientists, but an inspiration to the next generation of Earth warriors on how they might make a difference in the world.

REWILDING

THE RADICAL NEW SCIENCE OF ECOLOGICAL RECOVERY

AUTHOR **PAUL JEPSON & CAIN BLYTHE**
PUBLISHER **ICON BOOKS / MIT PRESS**
PRICE **£18.99 / $29.95**
RELEASE **OUT NOW**



At a time when scientists, ecologists and environmentalists are working tirelessly to help rebuild and conserve our environment, many methods of rescue are being explored. One such method is rewilding, which this book compellingly introduces and examines. The aim of rewilding is to reconnect interactions between plants and animals that may have been lost over time.

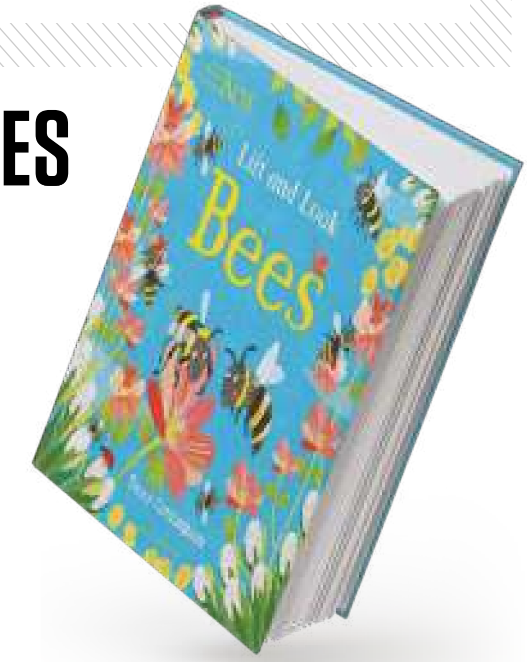
The authors are ecologists who expose the reader to the science of rewilding in an accessible tone, introducing the evolution of ecosystems and providing examples of successful rewilding projects from around the world. They offer fascinating predictions of the impact that rewilding can have. Vibrant and easy-to-follow infographics and illustrations dotted throughout the book make easy work of supporting explanations of scientific principles and processes.

Rewilding is a fascinating read for not only the ecologically minded, but also anyone that wants to better understand how all life on Earth functions together and the importance of maintaining different ecosystems.

LIFT AND LOOK BEES

UNCOVER THE LIVES OF THESE BUSY INSECTS

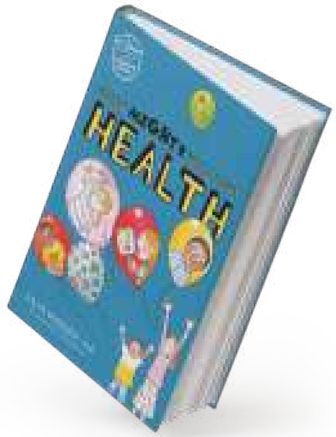
AUTHOR **TRACY COTTINGHAM**
PUBLISHER **BLOOMSBURY**
PRICE **£7.99 / $9.47**
RELEASE **OUT NOW**



The lives of honey bees are largely hidden away in hives, but this interactive book helps children to explore the busy communities that thrive in bee hives. Under each flap lies a fascinating fact about these striped insects. Who is in charge? What do they do all day? Why do they dance? *Lift and Look Bees* answers them all and more.

To complement the text, the pages are filled with vibrant imagery of friendly faced bees. These illustrations help the reader visualise the layout of honeycomb and observe the path of a bee's dance. But their lives in the hives are just half of the story. *Lift and Look Bees* explains to children why you often see them flying purposefully from flower to flower. Lifting the flaps reveals some of the foods that wouldn't be able to thrive and grow without bees – most of which young readers will be familiar with.

While it's short and honey-sweet, this book provides just enough information for children who are being introduced to bees. It gives them an insight into a bee's life and explains why we should care for them.



FACING MIGHTY FEARS ABOUT HEALTH

ENGAGING ANSWERS TO CHILDREN'S WORRIES

AUTHOR **DAWN HUEBNER**
ILLUSTRATOR **LIZA STEVENS**
PUBLISHER **JESSICA KINGSLEY**
PRICE **£10.99 / $14.95**
RELEASE **21 APRIL**

At any age, it's common to have fears about our health. For young people who don't understand many biological processes, certain feelings in the body can be more overwhelming. *Facing Mighty Fears About Health* focuses on reducing health-related fears for young children by following four guided steps. The first is to understand how the body works, and this book covers many of the questions kids may have about health. Fun facts are dispersed throughout the pages, enabling children to explore their bodies' capabilities with awe rather than fear. For example, did you know that the heart beats around 36 million times a year? Or that you could fill a water bottle every day with the volume of saliva your mouth produces?

This book recognises that learning about human anatomy can lead to further questions, and has more reading to help with potential follow-up questions. As the title suggests, *Facing Mighty Fears About Health* teaches how to approach health anxieties in a reassuring tone. Comparing the body's warning system to a smoke alarm, the author provides children with a way to visualise and manage their anxiety. By following the advice in this book with a parent or guardian, children are sure to start feeling more comfortable in their bodies.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	5	4			7	2	8	
2	6	1	8			4	9	7
	8		4		1	6		5
5	7				8			4
	3	2			5	1		6
1					2	9		
4		8					1	9
7				1		8		3
6					9	5		

MEDIUM

3	5						8	
					7	2		
	7	1	4					
		5					1	
4		2	8		5	7		9
	1		6	3	9			4
						1		
9		7		5	1		4	
1	6		7	4			5	3

HARD

						7	3	
		9	2	4				
				3		2		
				6	3			
7		2						8
	8	3	7					9
	6		3	9	8			1
	9							
3	7				3		5	

Word search

Find the following words

STALAGMITE
DIVER
EXOPLANET
CLOUD

FLIGHT
ARISTOTLE
POISON
RADAR

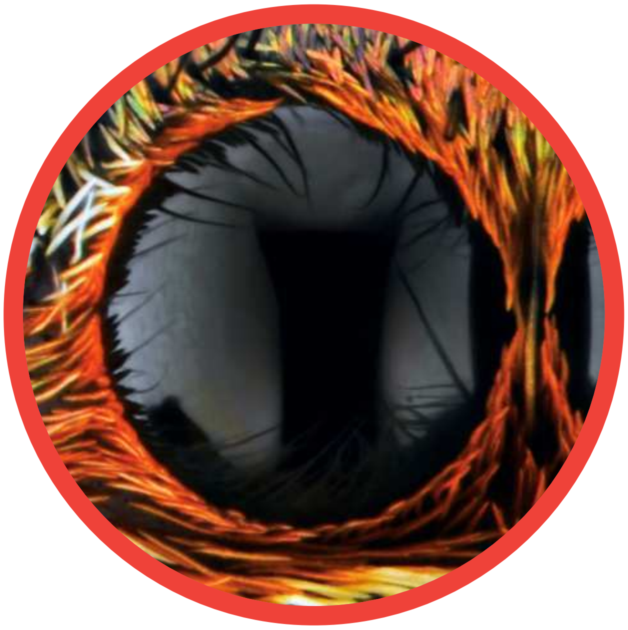
BULB
LANDER
MOON
DISASTER

S	P	O	U	N	L	R	I	N	U	D	I	S	A	U
T	M	I	P	O	I	S	O	N	Y	I	N	M	F	J
A	K	C	L	U	O	D	A	R	A	S	I	O	V	E
L	D	I	V	R	C	L	F	L	D	A	T	O	P	E
A	J	R	A	D	O	I	L	U	B	S	O	N	I	P
G	O	B	E	M	G	H	O	A	R	T	I	V	T	F
M	A	L	O	P	R	L	I	G	R	E	L	K	E	O
I	R	U	W	A	C	H	F	L	A	R	I	O	N	E
T	A	B	A	R	I	R	S	T	D	O	T	L	A	D
E	X	Q	P	L	E	A	N	I	A	S	A	S	L	T
B	U	L	E	D	D	I	V	E	R	G	M	I	P	E
S	T	A	N	E	X	A	Y	O	P	A	K	E	O	U
R	F	A	L	I	G	H	I	A	R	P	O	N	X	E
T	L	H	V	E	T	H	G	I	L	F	C	L	E	U
B	A	R	I	S	T	O	T	L	E	C	H	I	P	O

What is it?

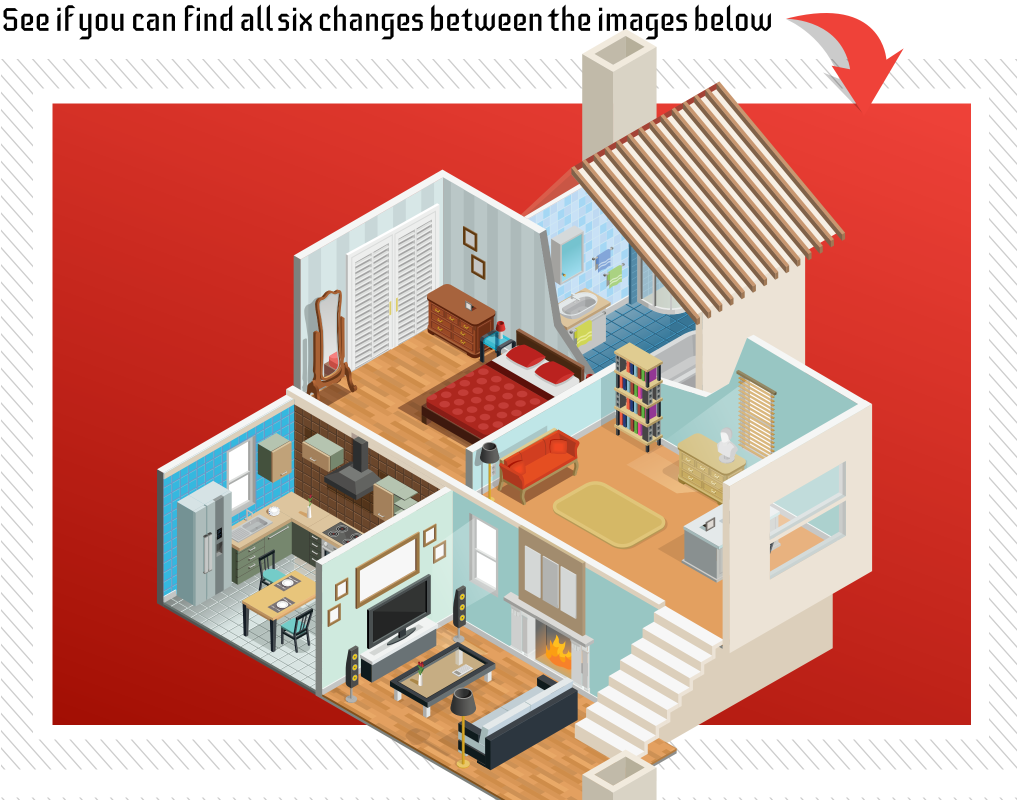
Hint: This creature has eight of these

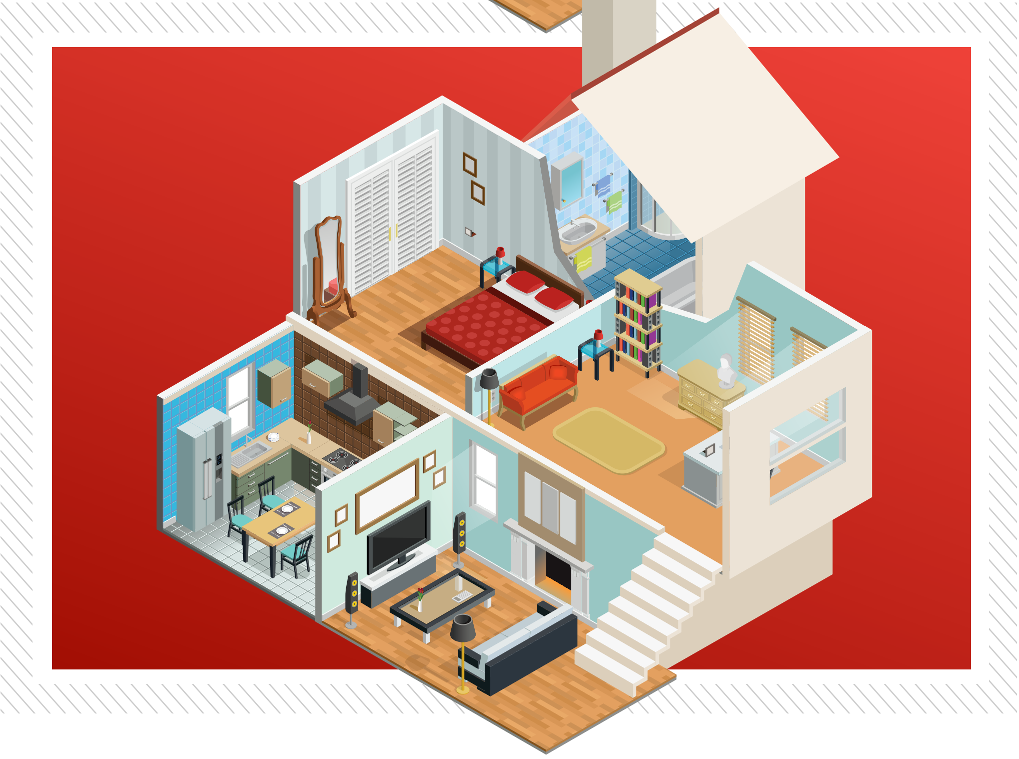
A



Spot the difference

See if you can find all six changes between the images below





Answers

Find the solutions to last issue's puzzle pages

Q1 DRAGONFLIES
Q2 GANYMEDE
Q3 FOSSILISED CREATURES
Q4 1 QUADRILLION
Q5 LOW METABOLISM
Q6 POSITRON

What is it?

SNOWFLAKE

Spot the difference

QUICKFIRE QUESTIONS

Q1 Which of these vehicle types combine internal combustion and electric engines?
○ Biodiesel
○ Hybrid
○ Hydrogen fuel cell
○ All-electric

Q2 Where can you find a shrimp's heart?
○ By its head
○ In its tail
○ Just behind its eyes
○ In its chest

Q3 What is an event horizon?
○ A region around a black hole
○ The moment the Sun rises
○ Light curving around Earth
○ All of the above

Q4 What was the first computer mouse made of?
○ Wood
○ Plastic
○ Metal composite
○ Gold

Q5 Which of these chemical elements catches fire in air?
○ Helium
○ Silver
○ Plutonium
○ Rubidium

Q6 What war followed Franz Ferdinand's assassination?
○ World War II
○ World War I
○ The Gulf War
○ The Vietnam War

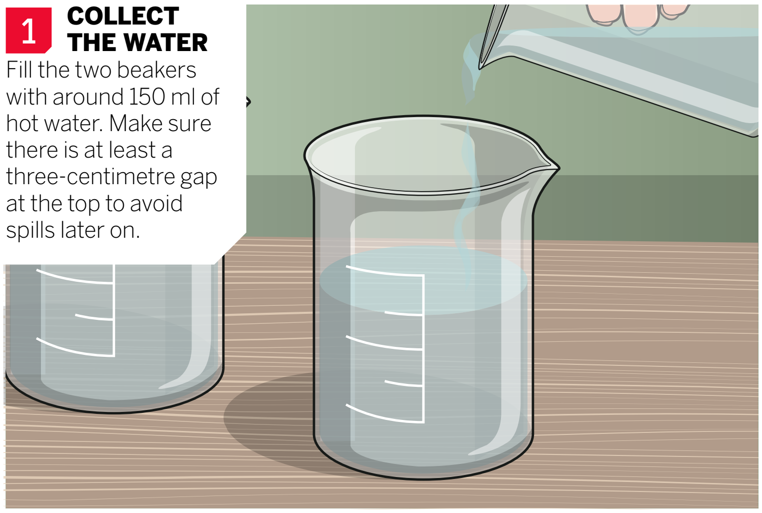
© Alamy / Getty

MAKE A STALACTITE

Follow these simple steps to emulate the mineral pillars seen in caves

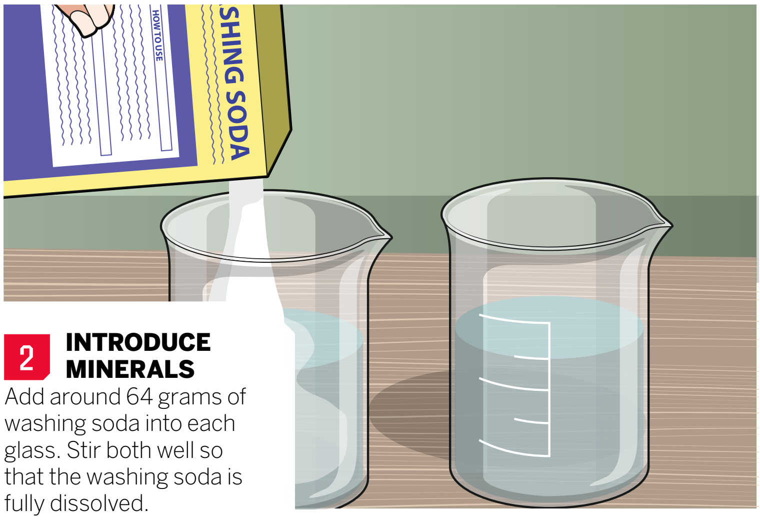
KIT LIST

- Two pyrex glasses or beakers
- Water
- Washing soda
- A cloth or thick string
- String
- Scissors



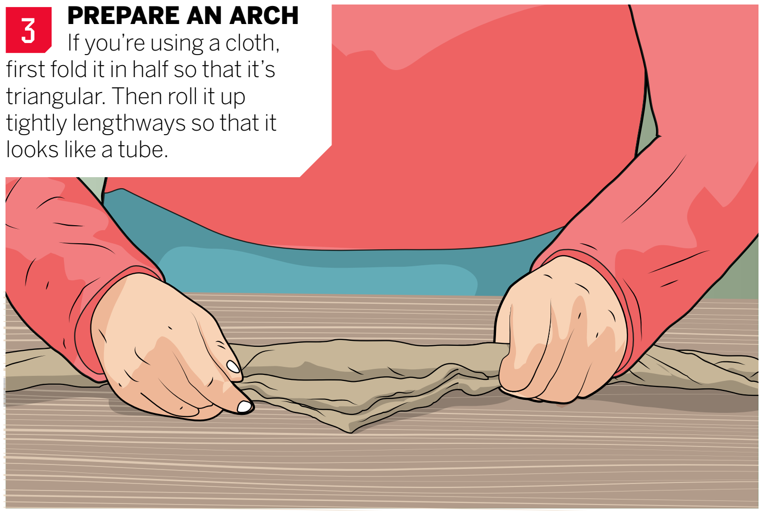
1 COLLECT THE WATER

Fill the two beakers with around 150 ml of hot water. Make sure there is at least a three-centimetre gap at the top to avoid spills later on.



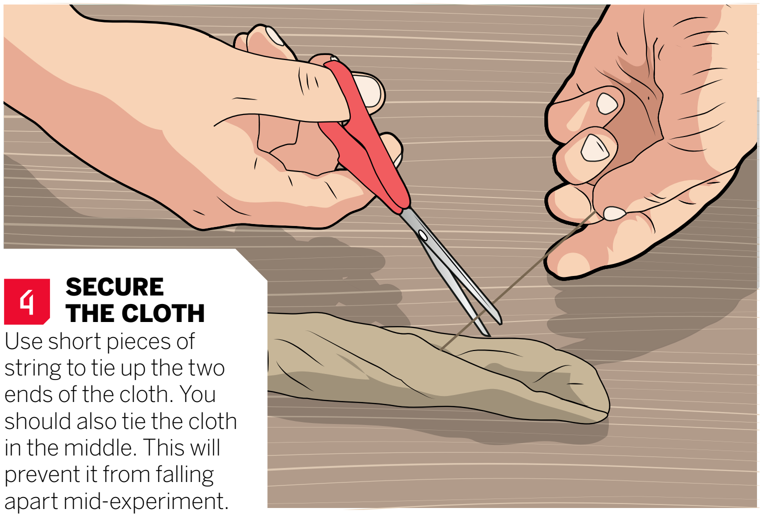
2 INTRODUCE MINERALS

Add around 64 grams of washing soda into each glass. Stir both well so that the washing soda is fully dissolved.



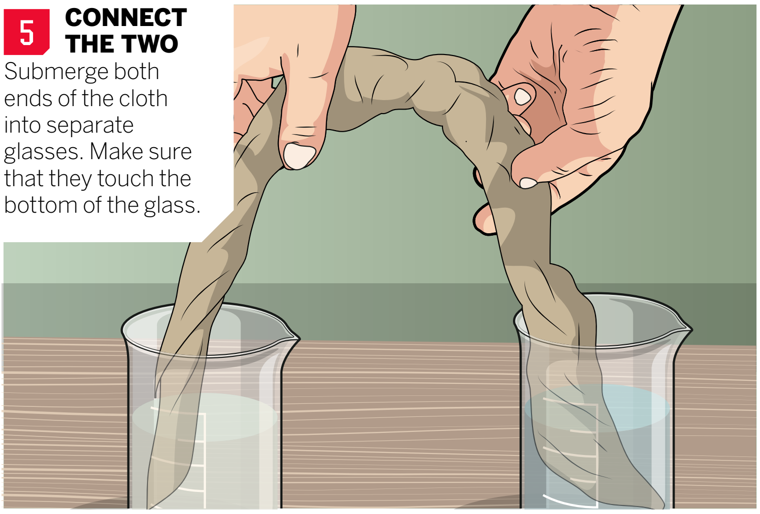
3 PREPARE AN ARCH

If you're using a cloth, first fold it in half so that it's triangular. Then roll it up tightly lengthways so that it looks like a tube.



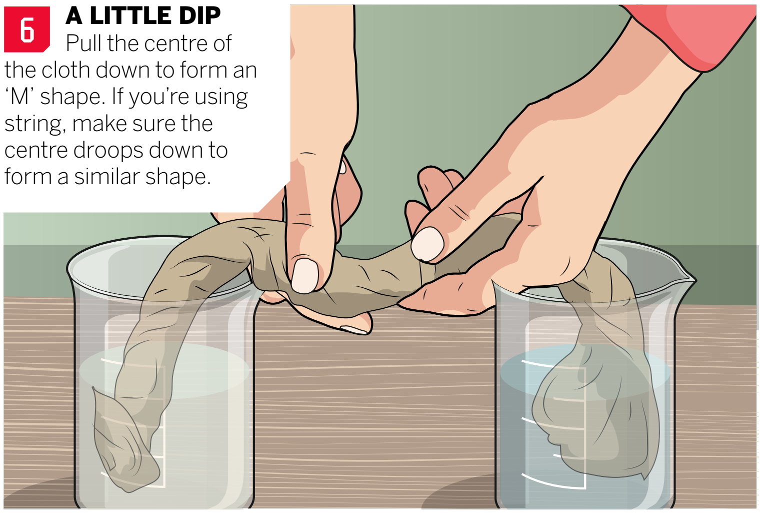
4 SECURE THE CLOTH

Use short pieces of string to tie up the two ends of the cloth. You should also tie the cloth in the middle. This will prevent it from falling apart mid-experiment.



5 CONNECT THE TWO

Submerge both ends of the cloth into separate glasses. Make sure that they touch the bottom of the glass.

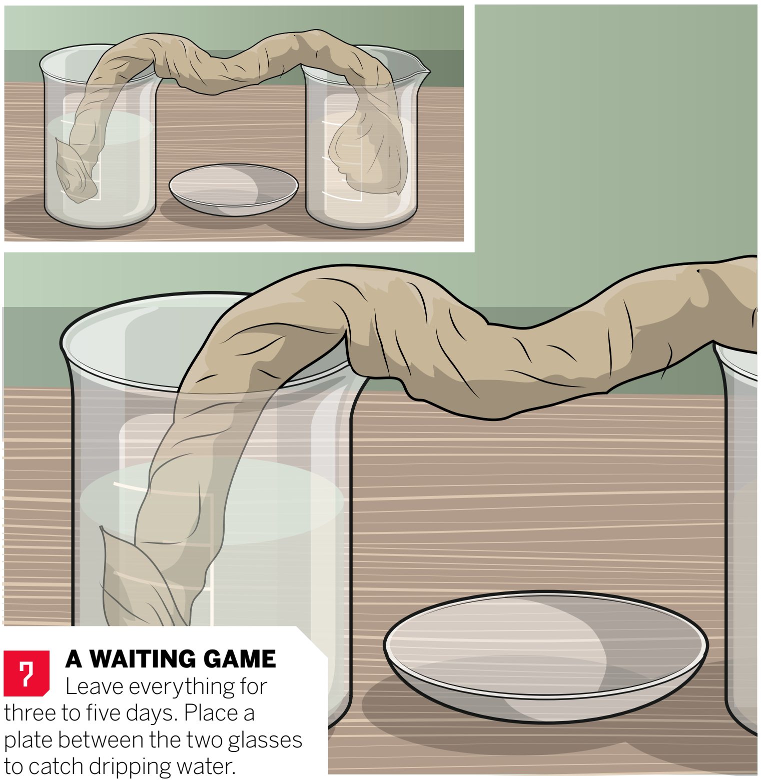


6 A LITTLE DIP

Pull the centre of the cloth down to form an 'M' shape. If you're using string, make sure the centre droops down to form a similar shape.

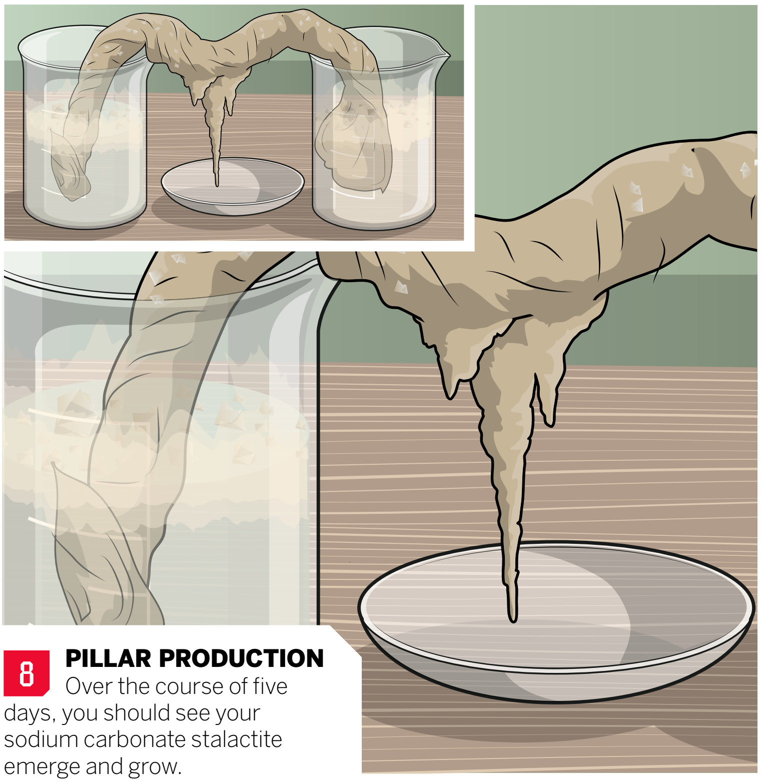
NEXT ISSUE
HOW TO MAKE A THUNDERSTORM IN A TANK

DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you



7 A WAITING GAME

Leave everything for three to five days. Place a plate between the two glasses to catch dripping water.



8 PILLAR PRODUCTION

Over the course of five days, you should see your sodium carbonate stalactite emerge and grow.

SUMMARY

You may have become impatient over the course of five days, waiting to see your stalactite grow. However, this is record speed compared to the time caves take to produce theirs – it takes around 100 years for a stalactite to gain just one centimetre in a cave! But what is happening during this time?

Just as the water travelled through the holes in the cloth towards its centre, rainwater can travel through the rock of caves. As rain passes through this organic material, it mixes with carbon dioxide gas to form carbonic acid. Stalactites usually form in limestone caves; limestone is 50 per cent calcite, a form of calcium carbonate. This mineral is dissolved from the rock by the acid. The rainwater is now a liquid containing dissolved minerals. When it emerges from the cave's ceiling, it's exposed to air, and the calcite mineral is solidified again.

In this experiment, washing soda was used, containing sodium carbonate. It's this that solidifies as water leaves the cloth. This process continues as long as there is a water supply. Water runs down the stalactite, depositing minerals at its end and causing it to grow.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

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WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

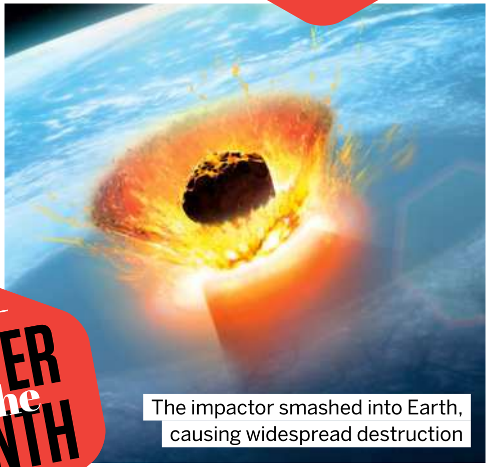
LIFT AND LOOK BEES

With bright illustrations and simple, accessible and interactive text, this is the perfect first introduction to bees for preschoolers. Little ones will even meet the queen bee!

EARTH IMPACT

LETTER of the MONTH

Dear **HIW**,
We've just learnt about the mass extinction of the dinosaurs about 66 million years ago. I was wondering what it would feel like if the exact same meteor was to strike in the exact location today.
William Wu



The impactor smashed into Earth, causing widespread destruction

Thanks for your interesting question, William. What we know about the impactor that wiped out the dinosaurs is that it was roughly six miles in width. The result of the collision was a giant explosion, creating a crater about 111 miles wide. If the same event were to happen again, we could expect similar conditions to arise.

The huge mass of debris thrown into the air would alter the atmosphere for a long time, blocking sunlight. We can only imagine the feeling, but the shock wave that was created has been compared to a gunshot multiplied to the size of a planet. What would follow is a massive tsunami, as the force would displace a great amount of seawater. If the impact occurred in the exact same place again, in Mexico, the tsunamis and earthquakes would be felt as far away as Argentina.

Today, such an impact is less likely to occur completely out of the blue. NASA can detect massive threats to the planet through sophisticated tracking systems. By collecting radar tracking data, we are able to monitor the orbital paths of large asteroids and predict their future movements. Asteroid-diverting technology is also being tested.

MAKING MACARONI

Dear **HIW**,
I'd like to know how macaroni is made and how they put the hole down the middle of the little tubes.
Hani Khaliq

As you'll have noticed, macaroni is a small, delicate shape. Yet in each packet every pasta piece is uniform, with the central tube being an ideal feature when filled by your sauce of choice. Macaroni begins as a dough made of durum wheat, semolina flour and water. This is kneaded to create the optimum consistency for shaping. Machines pipe the dough through a metal mould, called a die. This die has different shapes based on the type of pasta being made.

As dough is pushed through the macaroni die, which has an 'O' shape, it comes out as thin, hollow tubes. As the shapes emerge from the die, the dough is cut periodically by sharp blades to keep each length of macaroni the same.

Macaroni being laid out to dry

NEXT ISSUE

ISSUE 161

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FESTIVE LIGHTING

Dear **HIW**,
Many houses are lit up for Christmas and other winter celebrations. How much more electricity does the world use because of this?
Chelsea Holt

The twinkling of lights is very noticeable at this time of year, but few think about the bigger impact. This was also considered by the energy company Arcadia, who worked out how much energy was being used, but also analysed the extra cost of these festive additions. With an estimate of one home using about nine strings of 100 bulbs, if these lights were on for six hours a day, 65kWh of electricity would be used throughout December for that home.

The study focused on the US, finding that 90 per cent of homes celebrated Christmas. Based on the estimate that around half of the houses in the country were lit up, 3.5 billion kWh is consumed in December. In the US alone, the cost of running these lights adds up to $645 million (£480 million).

Some people decorate their house with lights in winter

High chlorine levels decrease the pH of water

POWER OF CHLORINE

Dear **HIW**,
I love the smell of chlorine, but how much of it is needed in a swimming pool? Is it dangerous to be exposed to it for too long?
Noa Zimman

Chlorine is used as a first defence against any germs that may arise in swimming pools. In a swimming pool with an optimal pH level – between 7.2 and 7.8 – chlorine can kill the majority of germs within a few minutes. When chlorine is added to a pool, a portion of it is used in disinfection. This is known as chlorine demand. During this process, hypochlorous acid is formed – also called free chlorine residue. It's the free chlorine residue that's detected when reading chlorine levels in a pool. This is usually kept between one and three parts per million. Exposure to this level isn't considered dangerous, but if you were to be exposed to chlorine levels higher than this, the increased acidity could irritate your lungs, eyes and skin.

Children usually prefer sweeter foods

CHANGING TASTE

Dear **HIW**,
Do foods taste different when you're an adult compared to when you're a child? There are so many foods I used to hate but now quite like.
Dorian White

This is a very common experience, and could be due to the differences in children's and adults' taste buds. These clusters of sensory cells detect different flavours. As children, more of our taste buds detect sweet tastes. This can make us more sensitive to bitter tastes when we are younger. Some of the foods you like now may have tasted much more bitter when you first tried them!

WE ASKED YOU

This month on Instagram, we asked you: If you held the power to control the weather on Earth, what would you change about it?

@YOUNGINSON

No summer and no winter period

@SCIMAXFACTS

More snow in areas like England during the winter and consistent sunny summers

@CAROLJSHELDON

Keep it between 15 and 30 Celsius

@FAARIS_HAQUE

This England weather

@MAIA_H3

I'd stop the extreme droughts caused by global warming

@COACHADRIANMATEI

Regenerate the soils

@MERLE.HAHA

Give everyone a remote control to choose their own weather

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FAST FACTS

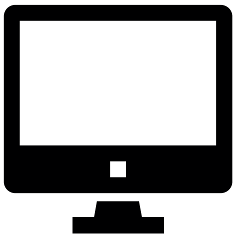
Amazing trivia that will blow your mind

2,400

Thousands of nukes have been detonated since 1945

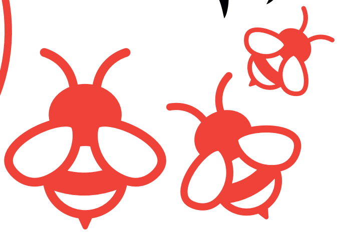
3

Cuttlefish have hearts in three different parts of their body



0.3 MILLIMETRES

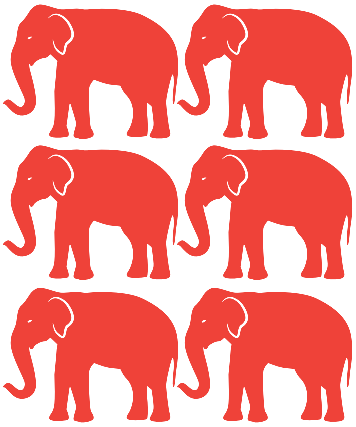
The world's smallest computer is smaller than a grain of sand



BEES HAVE BEEN TRAINED TO PLAY FOOTBALL

1897

In this year, candy floss was invented… by a dentist



33 TONNES

In his lifetime, the average man will eat the weight of six elephants

Uranus has a moon named Margaret

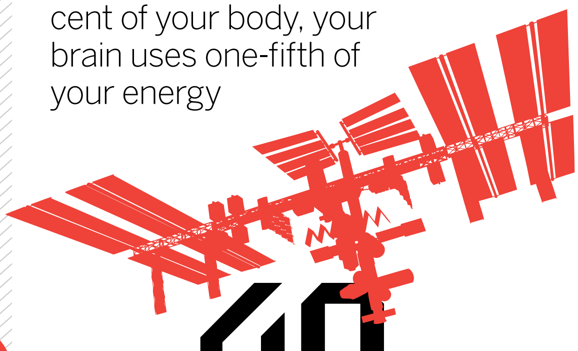
20%

Despite being just two per cent of your body, your brain uses one-fifth of your energy

THE ROMANS USED HUMAN AND ANIMAL URINE TO CLEAN THEIR TEETH

43

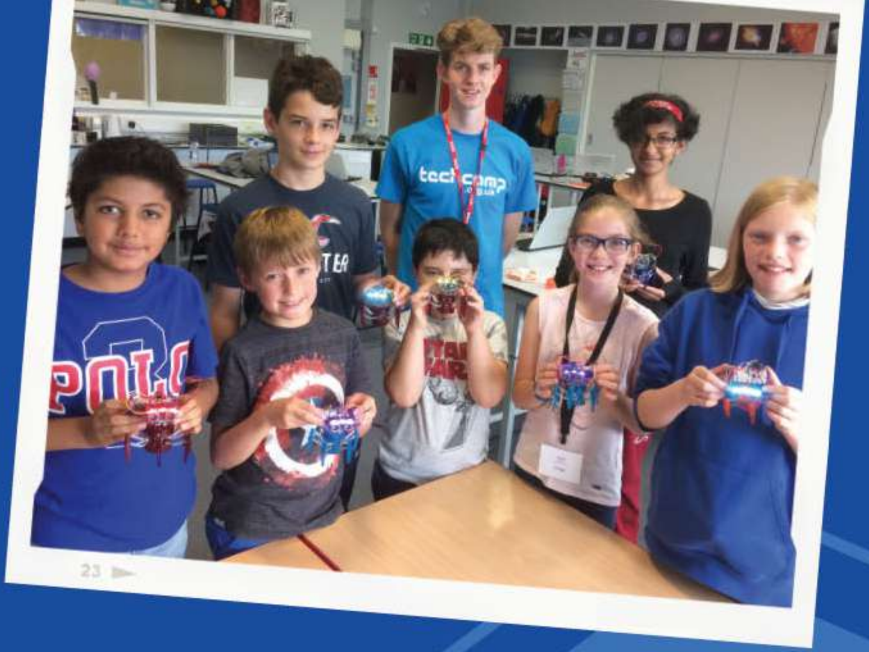
The number of computers connected to the internet in 1973



40 MINS

It takes the International Space Station less than an hour to travel from the UK to Australia

© Getty



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American single-seat, single-engine, all-weather stealth multirole combat aircraft that is intended to perform both air superiority and strike missions. It is also able to provide electronic warfare and intelligence, surveillance, and reconnaissance capabilities. Lockheed Martin is the prime F-35 contractor, with principal partners Northrop Grumman and BAE Systems.

The aircraft descends from the Lockheed Martin X-35, which in 2001 beat the Boeing X-32 to win the Joint Strike Fighter (JSF) program. Its development is principally funded by the United States, with additional funding from program partner countries from NATO and close U.S. allies, including the United Kingdom.

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